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ASTROPHYSICS.—*The physical chemistry of a cooling planet.*[1] P. G. NUTTING.

A planet, starting as a mass of vapor torn from the sun and approaching the present condition of the earth, must pass through a number of well-marked epochs as its temperature falls. Its initial and final states may be studied, but intermediate conditions must be arrived at by deduction from the amounts of various elements present and their physical and chemical conditions at various temperatures. What would be the first crust to form, what was the composition and pressure of the atmosphere at a certain surface temperature, when did the ocean start, and how rapidly did it grow? The answers to these and similar important geologic questions may be obtained in approximate form from known data and principles, yet this field has aroused little interest. While the critical constants of a few elements and the dissociation constants of many minerals are still unknown, the lack of these introduces only minor uncertainties in the results.

The writer in 1926 presented a brief outline[2] of the epochs through which a cooling earth must have passed, omitting most of the physical relationships (assumed well known) used in arriving at the conclusions. Quotations from that paper by geologists indicate that the subject should be covered in far more detail. The objective is to reconstruct a history of the earth, not on a time scale but on a temperature scale, which is far more interesting and important to geologists.

Aside from temperature, the elements to be dealt with are those listed by F. W. Clarke in his *Data of geochemistry* as constituting the 10-mile crust of the earth. Whether the bulk of the core consists chiefly of iron is of little consequence in the surface phenomena under discussion. Having a critical temperature probably above 4,500° K., iron would become a fluid sphere at an early stage. Iron alloys freely with but relatively few other metals (nickel, chromium, manganese . . .), and the nature of the residual vapors trapped in crustal rocks suggests the dominance of iron in any alloys that may constitute the earth's core. Clarke's tables show how eruptive rocks (95 percent) dominate the lithosphere, for the weighted average of all portions, including the oceans, the atmosphere, and all sedimentary rocks, differs very little from that of the eruptives; also that the hydrogen as water, the nitrogen of the air, and the carbon of living things, coal, and oil, so prominent in our lives, are almost negligible relative to other elements.

In Table 1 are given Clarke's weighted mean relative amounts of the various elements occurring in the earth's 10-mile crust, including the hydrosphere (oceans and lakes) and the atmosphere. To these have been added lists of the melting points, boiling points at present atmospheric pressure and critical temperatures, all on the absolute scale (273+° C.). The fourth column is obtained from the third by multiplying by 1.5 according to the Guldberg rule that the boiling point is always about two-thirds of the critical temperature on the absolute scale. It varies from 0.58 to 0.66 in known cases.

A temperature of 5,000° is reasonable for a planet just drawn from the sun by a passing star. At 5,000° there are, of course, *no compounds* present, and Table 1 shows that there can be *no liquids*, for all elements

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[2] NUTTING, P. G., *Pressures in planetary atmospheres.* Journ. Washington Acad. Sci. 16: 254. 1926.

TABLE 1.—ELEMENTS OF THE EARTH'S CRUST

Element	Relative abundance	Melting point °K.	Boiling point °K.	Critical temperature °K.
Oxygen	46.20	54.8	90	155
Silicon	25.67	1680	2870	4300
Aluminum	7.50	932	2070	3100
Iron	4.71	1708	3300	4900
Calcium	3.39	1080	1440	2160
Sodium	2.63	370.7	1153	1730
Potassium	2.40	335.5	1033	1550
Magnesium	1.93	924	1380	2070
Hydrogen	0.87	14.0	20.4	32
Titanium	0.58	2070	3300	4900
Halogens	0.22	171 (Cl)	240	360
Phosphorus	0.11	317	553	830
Manganese	0.09	1530	2170	3250
Carbon	0.08	3800	4500	6700
S, Ba, Sr, N	0.15	—	—	—
All others	0.47	—	—	—

except perhaps carbon are above their critical temperatures. Transmutations of elements, such as go on in the larger hotter stars, will have ceased except for the slow decay of a few scarce radioactive ones. Pressures near the center must have been near what they are now, about 17×10^5 atmospheres or 12,500 tons per square inch.

At 5,000° such a mass of dense vapors would be subject to rapid cooling by radiation from its outer layers. Only a slight cooling would permit combinations of the elements (as oxides, carbides, etc.) with an evolution of heat amounting to a few hundreds of (kg) calories per gram. Such compounds would condense to liquids and fall back as rain to where the temperature was sufficient to vaporize and redissociate them, exciting visible *line spectra* of the elements. Thus such a mass of vapors would possess a bright *photosphere*. Chemical combination excites only band spectra and these chiefly in the infra-red. A mass of matter at 5,000° would in short be a violently agitated body of elementary vapors having a photosphere giving off bright-lined spectra of all elements but containing no liquids or chemical compounds except at extreme heights. The rapid transfer of heat by dissociation and combination farther out as well as by radiation and convection is being given attention by astrophysicists and is of primary importance.

At 4,000° conditions are vastly altered. Iron, titanium, and silicon are below their critical temperatures and hence will largely condense to form a *liquid core*, a core containing minor amounts of tungsten, molybdenum, and other metals as alloys, and possibly a little of a few oxides and carbides in solution. There is little information on phase relations, critical temperatures, and dissociation constants at such temperatures. From the relatively low stability of iron oxides and carbides, liquid iron at 4,000° would be expected to float the stable carbides and oxides of other metals. In Table 2 are collected the available data on the higher melting compounds.

TABLE 2.—HIGHER MELTING COMPOUNDS

Compound	Melting temperature °C.	Boiling temperature °C.	Compound	Melting temperature °C.	Boiling temperature °C.
AlN	2,200	(Decomp.)	La_2O_3	2,000	4,200
$MgAl_2O_4$	2,135	—	MgO	2,800	—
Al_2O_3	2,050	2,250	MnO	1,650	—
BaO	1,923	(2,000)	Mn_3O_4	1,705	—
$BaSiO_3$	1,604	—	Mo	2,620	3,700
Be_3N	2,200	d 2,240	MoC_2	—	4,500
BeO	2,570	3,900	SiC	2,700	—
Boron	2,300	2,550	SiO_2	1,700	d 2,200
B_4C	2,350	3,500	ThO_2	2,800	4,400
BN	2,730	(Subl.)	TiN	2,930	—
CdS	1,750	(Subl.)	W	3,370	4,727
CaC_2	2,300	—	WC	2,777	(6,000)
CaO	2,572	2,850	UC_2	2,260	4,100
CeO_2	1,950	—	VC	2,830	3,900
Cr_3C_2	1,890	3,800	ZrO_2	2,700	4,300
Fe_2O_3	1,565	—	$ZrSiO_4$	2,550	—
Fe_3C	1,875	—			

Pressures at 4,000°, due to the atmosphere above the liquid surface, can only be guessed without a much more complete knowledge of high-temperature compounds. That pressure was certainly more than the weight of the 10 mile crust (4,300 atmospheres or 32 tons/sq. inch) and probably less than ten times that. It was certainly well over all known critical pressures so that all elements having critical temperatures below 4,000° were either liquid or solid. Those having critical temperatures above 4,000° were vapors.

Of the few compounds probably stable (undissociated) at such temperatures and pressures, the carbides of boron, calcium, chromium, molybdenum, silicon, vanadium, and uranium and the oxides of beryllium,

calcium, magnesium, lanthanum, thorium, and zirconium seem the most likely. Other oxides and carbides than those would be too unstable to exist except as transients in the outer layers. There were certainly no nitrides or silicates of any kind. The spectrum of a planet at 4,000° would still consist chiefly of bright lines with some even reversed but all on a continuous background.

At 3,000–2,500°, while the core is still liquid iron and iron alloys, the *first solids* appear, probably as float on the liquid sphere. The list of stable oxides and carbides is the same as at 4,000°. However, some of these, such as WC and UC_2, are heavier than iron and would sink in it, perhaps decomposing and losing their carbon to the iron. Of the compounds that are stable and solid at 2,500°, probably the more important are the oxides of beryllium, calcium, magnesium, and zirconium; silicon carbide (carborundum) and titanium nitride. The light carbides of boron and calcium freeze at about 2,300°, and should be abundant in liquid form at 2,500°. There is still no permanent silica or silicates as these decompose at about 2,200°. Aside from the appearance of the first stable solids the picture at 2,500° differs little from that at 4,000°.

Hydrogen and nitrogen require special consideration at this point. While according to Clarke (Table 1) hydrogen constitutes less than 1 percent of the 10-mile outer layer, it is sufficient to form all the oceans or enough to cover the entire earth to a depth of 2,600 meters or 1.6 miles. There was abundant oxygen to combine with the hydrogen; there is free oxygen today, in the air. Very little hydrogen could have been used up in hydrides for these are readily dissociated at high temperatures. Also very little nitrogen was used as nitrides for the same reason and much of it still remains free. Free carbon, however, is practically nonexistent. Clarke's data cover carbon chiefly as carbonates, hydrocarbons, and carbon dioxide, but not deeply buried carbides of which there may have been large quantities. At 2,500° there could have been no hydrocarbons or carbonates; the question is the probable division of carbon between the dioxide and the metal carbides, particularly silicon carbide, which must have been abundant in vapor form since it sublimes far below its melting and dissociation temperatures.

Both water vapor and carbon dioxide are very stable at high temperatures as shown in Table 3 taken from Nernst's *Theoretical chemistry*, 5th English edition, p. 783; data of Bjerrum and others taken about 1912 by an ingenious and precise explosion method. Dissociations are given for six temperatures and three pressures for each gas, in percentages.

TABLE 3.—DISSOCIATION OF WATER AND CARBON DIOXIDE

°K.	Water vapor			Carbon dioxide		
	1 atm.	10 atm.	100 atm.	1 atm.	10 atm.	100 atm.
1,000..	2.58 $\times 10^{-5}$	1.29 $\times 10^{-5}$	0.556 $\times 10^{-5}$	2.47 $\times 10^{-5}$	1.14 $\times 10^{-5}$	0.531 $\times 10^{-5}$
1,500..	0.0202	0.00935	0.00433	0.0483	0.0224	0.0104
2,000..	0.582	0.270	0.125	2.05	0.960	0.445
2,500..	4.21	1.98	0.927	17.6	8.63	4.09
3,000..	14.4	7.04	3.33	54.8	32.2	16.9
3,500..	30.9	16.1	7.79	83.2	63.4	39.8

Log dissociation plotted against either 1/T or log pressure gives essentially a straight line. Dissociation is small except at the higher temperatures and decreases markedly at high pressures. In a contest between oxygen and silicon for the carbon it is difficult to say which would be favored but both compounds would be present.

With a surface temperature of 2,500° the earth's atmosphere at lower levels must have consisted mainly of heavy metallic vapors and the vapors of a few stable compounds of high density. These would condense at higher levels, rain down, and revaporize. Iron was probably metallic but may have been present as oxide. At intermediate and higher levels were large known quantities of water vapor (1.85 tons per square inch) mixed with large but uncertain amounts of carbon dioxide. The water would condense and rain downward much as it now does but in enormously greater volume and never reaching the surface. At the outer limits would be cool free gases.

The observed outer atmospheres of Jupiter and Saturn invite the question of what

happens when the proportion of hydrogen is large rather than small as on the earth. Abundant hydrogen, with plentiful nitrogen and but limited oxygen, would make possible the formation of much *ammonia* to form a cool, stable outer blanket, even with a core temperature of a thousand degrees.

At 1,500° to 1,200° the surface is vastly different from what it was at 2,500°. *Silica* and *silicates* have formed, some in solid others in fluid condition. All are fairly stable below 2,000°. They would cover the old core *miles deep* and suppress, chiefly as silicates, all but a few metallic vapors. At least the more volatile silicates would form the bulk of the lower atmosphere and would vaporize, rise, and reprecipitate in enormous storms. The lower layers of silicates would contain the less volatile metals, oxides, and silicates; the outer layers were probably the original igneous rock of the present lithosphere. There were still no *carbonates* and, of course, no hydrocarbons, and the water was still all in the outer atmosphere.

At 500° C. (a dull red heat) many carbonates and some hydrates, fluorides, sulphides, etc., are stable, but most of these probably formed at lower temperatures, long afterward. The oceans were still in the vapor state at high levels of the atmosphere. Most of the acid anhydrides would be stable and in the air. Surface showers would consist largely of fused and vaporized salts. They must have been huge and violent compared with any present-day storms but trivial in comparison with the snowstorms of silica in the range of temperatures from 1,800° to 2,500°. The range from 400° to 700° might be called the *chemical epoch*.

At the critical temperature of water 374° C., atmospheric pressure was about 252 atmospheres, considerably higher than the critical pressure of water, 217.8 atmospheres. Hence, condensation of a fraction (0.137) of the water vapor to liquid water occurred as soon as the temperature fell below 374° C., and 13.7 percent ($=1-217.8/252.3$) of the total water must have become liquid as cooling proceeded beyond that point. That fraction of the total water is sufficient to cover the entire earth to a depth of $2{,}607\times0.137=357$ meters, or 1,171 feet. Local pressures in depressions may well have been several times that depth of water. Therefore in passing 374° C. pressures abruptly changed from an evenly *distributed* pressure of 252 atmospheres to one of 218 atmospheres plus *local pressures* of probably 300 atmospheres, an excess of 7 tons per square inch. This abrupt change from distributed to localized pressure was pointed out in *Science* (Oct. 1911) and further elaborated in my 1926 paper. At 300° C., two-thirds of the water was liquid and the pressure of the vapor about 85 atmospheres; at 200° C., 95 percent was liquid and the pressure 15 atmospheres.

The first oceans were therefore sizable bodies of water. Evaporation and precipitation must have been extremely rapid as was *solution* and *erosion*. Localized pressures must have caused considerable rock movements, chiefly lateral thrusts. The distribution of crustal strains must have varied considerably as the depth of the oceans increased. Some of the present elevated areas (the "positive" areas of paleogeographers) may have originated during this epoch.

The fall of mean surface temperatures below about 370° C. must have marked the beginning of the epoch of *hydration*, *solution*, and *sedimentation*—the water epoch—which is still in progress. At the higher temperatures, however, rates of solution and sedimentation must have been many times present rates. With all oceans boiling, and a continuously saturated atmosphere with copious rains of high-temperature water, all but the most insoluble rocks such as the granites, must have been rapidly eroded and redeposited. Overloaded solutions must have been abundant and violent in their activity, forming material that would later be comparable with the pegmatites. Owing to the size of the first oceans it appears doubtful whether they ever approached saturation in any constituent. Any attempt to calculate the age of the ocean on the basis of the present rate of accumulation of its salts must give results far from the truth.

Living matter and the formation of hydrocarbons from it became possible only in the

very recent thermal history of the earth when temperatures were not above 50° C. At about this stage the dense vapor blanket in the upper atmosphere, which previously had equalized polar and equatorial temperatures, probably thinned out sufficiently to permit polar regions to become cooler than equatorial. Hence, it appears probable that primitive forms of life originated in the polar regions. The carbon of all living matter, of course, all came from the CO_2 of the air, which is only 1 part in 30,000 of that fixed in the carbonate rocks. All this carbon is less than 0.1 percent (0.08 percent) of the earth's crust. How much more is still deeply buried as carbides we have no present means of knowing.

Attention should be called to the simple relation between the time and the temperature scales. Since the radiation (in energy per unit time) from a body is proportional to the fourth power of its absolute temperature and in this case the mass is constant, the specific heat and surface area are approximately so, and the cooling is all by radiation to space, the rate of energy loss is proportional to the rate of temperature lowering, dT/dt, which in turn is proportional to T^4. Hence,

$$dT/dt = CT^4 \text{ or } T^3 = at + b, \text{ by integration.}$$

In other words T^3 is a linear function of the time. The constant b depends on the chosen zero of time and a upon the time unit, years or millennia.

The writer has attempted to sketch the probable early physical history of the earth on a temperature instead of a time scale based on known physical chemical data and on the chemical composition of its surface. The subdivisions inferred are great natural epochs; all gas and vapor, the first liquid core, the first solids, the first stable silicates and the formation of the silicate crust, the formation of the first and later carbonates, the first surface water, the abrupt change in pressure distribution, and finally the formation of hydroxides and of hydrocarbons. The reasoning is speculative rather than deductive because of the lack of important data, yet the conclusions check well with known geologic facts, and it is hoped they may help to establish others. It is hoped also that it may further emphasize the value of physical chemistry in geologic studies.

OCEANOGRAPHY.—*Boundaries of the Humboldt Current.*[1] ELIOT G. MEARS, Stanford University. (Communicated by CLARENCE R. SHOEMAKER.)

Not until Gunther's report on the work of the *William Scoresby* became available was it possible to delineate with any degree of accuracy the boundaries of the Humboldt Current. Yet even at the present time these limits are still too indefinite to provide for the drafting of satisfactory graphs or charts. The southern boundary shifts with the seasonal march of the prevailing west wind zone; these shifts have not been determined, because the above examination occurred during the winter and did not afford data for summer, early autumn, or late spring in the Southern Hemisphere. The northern boundary vacillates with the southward approach of the warm countercurrent (commonly called El Niño) during the southern summer; this advance, although of annual occurrence, also has not been plotted.

Gunther's own account lacked in definition. His delimitation of the western boundary of the current proper was hindered by the invasions of warm-water wedges from the west during the time of his survey. For reasons attributed to economy, the expedition was unable to locate the western boundary of the Humboldt Current's so-called "oceanic twin" known as the Peru Oceanic Current, and, since this "oceanic twin" represents water affected by that of the Humboldt Current proper or its upwelling, naturally the westward ultimate limits of the Humboldt Current's effects have not been determined.

Furthermore, Gunther's exact data were secured in the single year of 1931. Schweiger's research, which has covered a period of

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16 years, indicates that 1931 was an abnormal year; in fact, it was one of a series of three years of attempted warm water invasions of major proportions (1942, p. 37). In that one year Gunther's observations were confined to the months from May to September for the entire examination, and he laments the brevity of time allotted the work because of the impossibility it allowed for noting variations which appeared to be striking during a single month, for instance, at Callao. He pointed out that a long-continued, consistent, and more widespread investigation was necessary to interpret and correlate these variations (Gunther, 1936, pp. 169, 170, 244). Nevertheless, Gunther's report represents the most careful scientific survey of the Humboldt Current that has been made; it does afford a basis for valuable generalizations.

Gunther defines the Humboldt Current as "a narrow belt of cold water which runs up the west coast of South America roughly from Valparaiso to the Gulf of Guayaquil. . . . It is that part of the South Pacific anticyclonic circulation in which the northerly current is most conspicuous; and whose physical, chemical and biological characteristics are most affected by admixture with water upwelled from the lower layers" (p. 109). It stems from the West Wind Drift, which is a much broader portion of the same anticyclonic movement.

The origin of the water in the Humboldt Current has been a much mooted question since Alexander von Humboldt suggested that it came from the Antarctic regions (1822, vol. 2, p. 59). But since Deacon's report to the Discovery Committee in 1937, it has become known that the Antarctic Convergence, which is the northern boundary of Antarctic surface water, occurs in the eastern Pacific between 80° and 90° west longitude farther south than 60° latitude (1937, pp. 38–39). The writer has found no statement of any evidence of the Humboldt Current farther south than 47½° south latitude, and Gunther places its probable extreme southern limit at 41° south latitude (1936, p. 172). Therefore, it appears that the Humboldt Current takes its origin some 15° or more northward of the limit of Antarctic surface water. It must be concluded that from its beginning the current is composed of subantarctic surface water.

This subantarctic surface water continues at the surface in the Humboldt Current, mixed, of course, with water upwelled at times from a warm subsurface current, until the cool current crosses the Subtropical Convergence, which Gunther located between 24° and 26° south latitude. In other words, in the southern winter of 1931, the subantarctic water remained at the surface as far north as the stretch of coast between Caldera and Antofagasta (1936, p. 159), or on about one-third of the current's early course. Over approximately two-thirds of the flow, therefore, but excluding the upwelled elements, the surface water is subtropical rather than subantarctic. Often marked by rip tides from horizon to horizon (Schott, 1935), the subtropical surface water remains at the surface until the Humboldt Current reaches its northern boundary, which is the Tropical Convergence. Here, at the surface, the Humboldt Current meets tropical water along an irregular line extending roughly from Punta Aguja to the Galapagos Islands. Since the current under discussion extends from its origin in the West Wind Drift to this northern boundary formed by the Tropical Convergence, it can be stated definitely that exclusive of upwelled elements the Humboldt Current consists at the surface of "two distinct water masses," the subantarctic and subtropical.

But since the feature that gives character to the Humboldt Current is its upwelling, Gunther assigns first importance to subantarctic water because the upwelling is drawn chiefly from subantarctic flow and comes from subsurface as well as from surface layers. At the Subtropical Convergence subantarctic water dives below the surface layer, yet it continues as a subsurface current as far as Callao. Throughout the survey of the *William Scoresby*, below the subantarctic water, indeed, below surface layers of whatever constituents, there was a southward moving, warm return subsurface current, beneath which Antarctic Intermediate water flowed northward. Normally,

the return subsurface current varied in depth from 40 to 150 meters, and reached a depth undetermined by Gunther's report, for he stated that upwelling never touched Antarctic water. Yet upwelling ranged from extremes of 40 meters to 360 meters, with a mean of 133 meters. During the period of the above examination, the surface layers and the subsurface return current were sufficiently thick to prevent the reaching of Antarctic water by the process of upwelling (1936, p. 200). This significant finding has not been accepted as yet by many leading scientists. For example, C. Vallaux (1939, p. 80), in reviewing the work of the *William Scoresby*, noted that there might be a slow rise of Antarctic Intermediate water. Sverdrup (1942, p. 189), in calculating the source of water within the Humboldt Current, includes the Antarctic Intermediate water.

Because of upwelling, Gunther's study very definitely fixes the lower boundary of the Humboldt Current at the stated 40 to 360 meters, with a mean of 133 meters, during the time of his survey; it excludes entirely all Antarctic water. Whether or not the current is deeper or shallower at other seasons and during other years remains to be shown by future investigations.

His eastern boundary appears, also, to be fixed. It is the coastline of the South American west coast between the northern and southern boundaries of the Humboldt Current. During times of normal strength and dominance of the Humboldt Current, it occupies the position inshore.

However, the writer wishes to point out that Schweigger's observations of the warm-water bands during 1939 and 1941, when the upwelling seemed to abate within the Humboldt Current, indicate a possible rise to the surface of portions of the warm, return southward-moving subsurface current. Temperatures below the surface at La Libertad, Ecuador, during 1938, point to a piling up of hot waters on the northern boundary of the Humboldt Current at the same time that the exceptionally strong Humboldt Current of 1938 reached its extreme minimum of temperature over a period of 16 years. When upwelling abated, it would appear that the pent-up, subsurface, warm, southward-moving current moved out more strongly. Schweigger found a warm, oceanic torrent along the outer shores of the islands in Pisco Bay during the autumn of 1939; a few miles southward of this torrent the normal Humboldt Current was encountered again. The torrent-force might be explained by the proximity of the strong Humboldt Current, which forced the return current to take its accustomed place beneath the surface.

That this theory is not entirely imaginary on the part of the writer is shown by the fact, that, when upwelling ceases along the shore washed by the California Current, the subsurface current rises to the surface and is known as the Davidson Current for the remainder of the year. But when upwelling returns in the following season, the Davidson Current disappears and there is discovered a subsurface current underneath (Sverdrup, 1941).

Therefore the writer would like to amend the statement of Gunther, and others, that the eastern boundary of the Humboldt Current is inshore along the western coast of South America between the northern and southern boundaries of that current. It is possible that it is inshore only until weak upwelling allows the rise of the warm return current to the surface.

The western boundary is far from definite. With reference again to Gunther's designation of the Peru Coastal, or more commonly called the Humboldt Current, this limit is the coastal strip of generally northward flowing water over which upwelling dominates. It must be noted that during the winter of his examination, he found it extended westward offshore approximately 30 to 130 miles from Chile, and 150 to 250 miles distant from Peru. Although he allowed considerable variation, due to the season and to warm water wedges he suspected that the modifications might exceed his appraisal (1936, pp. 109, 224). Within these longitudes, the temperature of the surface seawater dropped from 2° to 5° C. along the same parallel from the outermost stations to the innermost of those taken by the *William Scoresby*. For it is well known that the isotherms within the

Humboldt Current follow the coastline instead of assuming their normal east-west direction. The relative uniformity of the coastal cooling is caused by the upwelling, which is a distinctive characteristic of the Humboldt Current.

Therefore, the ultimate boundary of the current's influence should be along the points where the isotherms take their normal course. Since Gunther's investigations ceased before this change occurred, he pointed out that the extreme westward limits he assigned to the effects of the current were only an estimate. The area of marine, blue water affected by upwelled water from the Humboldt Current but not dominated thereby had a generally westward movement. He termed this outer flow the *Peru Oceanic Current.* He conjectured that the surface seawater, where the temperature was lowered by the upwelling along shore, extended some 300 miles seaward off the coast of Chile along the 40th parallel, and from 3,600 to 4,000 miles off the coast of Peru along the 15° parallel (1936, p. 224). The above lowered temperature limits could be detected only with a thermometer. The further westward extension of the Humboldt Current which the writer has discovered in existing literature appears in a note in *Science* (Beebe, 1926), where Dr. William Beebe reports that a captain on a United States vessel located the effects as far west as the Marquesas Islands, a distance of 3,711 miles from Callao. Perhaps it is reasonable to consider this the maximum outside limit, since this observation occurred during the most unusual year associated with the vagaries of the Humboldt Current. The date was September, 1925.

When the *Challenger* data were obtained it is assumed that conditions were not abnormal, but in the absence of records this conjecture can be questioned. It was from *Challenger* data that Thoulet (1928) reached the conclusion that the waters east of Easter Island were different in temperature, salinity, and density from those to the west. He attributed the difference to the effect of the Humboldt Current upon the waters to the east of the island; he called these waters the Easter Island Sea.

The stations of the *Challenger* were too few to enable Thoulet in 1928 to define boundaries of the Easter Island Sea other than to state that the sea was east of Easter Island. Since this island is approximately 2,000 miles westward from the South American coast in about 27° south latitude, Thoulet's finding fits roughly into Gunther's huge wedge-shaped area estimated to be affected by the Humboldt Current's upwelled waters. Indeed, Thoulet adds this one specific finding to supplement Gunther's observations and deductions.

The discovery made by Byrd's Expedition that Easter Island is situated upon the extensive Easter Island Ridge, which divides the South Pacific, appears significant to the writer because it forms the submarine demarcation between the East and West Pacific. The great submarine rise stretches from Ross Sea in the Antarctic (Roos, 1937), to the vicinity of the Gulf of California before it becomes indistinguishable from the continental shelf on the topographic map. Perhaps this ridge may be vitally related to the boundary of Easter Island Sea and to the ultimate westward effects of the Humboldt Current, for topography has a marked influence on current flow.

The northern boundary of the Humboldt Current, proper, has a seasonal variation that has not been precisely determined. Rainfall appears to be the most successful gage of the boundary's vacillation, for the dominance of the Humboldt Current is synonymous with aridity. According to rainfall records along the Peruvian coast (Eguiguren, 1894), the usual shift extends from Santa Elena Peninsula, which is the northern limit of the Gulf of Guayaquil, south to Punta Aguja. Farther west the Galapagos Islands appear to mark the normal north-south march of annual rainfall, but the data here have been secured from occasional expeditions and not from regular observations (Stewart, 1911).

Although most of the subtropical surface water is deflected westward of the Tropical Convergence, at this northern boundary of the Humboldt Current, there is evidence that some part, at least, continues as a surface current northward of that convergence.

Near the coast, according to Murphy (1939, p. 27), none of the Humboldt Current surface water reaches beyond the equator. Barlow (1938) is confident it flows at the surface northward of the Humboldt Current proper to the Gulf of Panama. Gunther (pp. 158–59) noted that a portion of the Humboldt Current surface water had sunk below the tropical water at the Tropical Convergence, and that it was still flowing north as a subsurface current at the northern extension of his survey. Fleming (1939, p. 173) found in the Gulf of Panama during the winter upwelling that the water has the character of the surface water off Peru. In other words, the extreme northern boundary of the Humboldt Current is yet to be determined.

Gunther (1936, pp. 162, 226–227) located the southern boundary during his survey on the 32nd parallel; nevertheless, he admits the possibility of an extension to the 40th parallel, in deference to Schott's chart, and he concedes a possibility of the 41st parallel as an extreme southern limit. But since Gunther actually observed the southern winter limit to be 32° south latitude, the writer prefers to retain that cold season border until further research, carried out in the same thorough manner as that of the *William Scoresby*, demonstrates the need of correction. In summer, there has been no determination comparable to the above. A characteristic feature of the Humboldt Current is the normal freedom from storms. For this reason, over a century ago Humboldt advised the use of this region for shipping, especially during such turbulent periods elsewhere (1829, vol. 6, p. 232). In January, 1939, Goodspeed's party observed that the storm-free character of the Humboldt Current protected their ship only part of the way between Valparaiso and Concepcion (Goodspeed, 1941). Thus, in the summer of 1939, the southern boundary of the Humboldt Current was between 32° and 37° south latitude. Yet it must be noted that 1939 was an unusual year of warm-water invasions.

There are other observations, but none, in the knowledge and opinion of the writer, that provide data with greater probability of accuracy. It has seemed wise to cite these specific fragments in order to show the meagre and inconclusive character of the information regarding boundaries of the Humboldt Current. Actually, only the lower boundary has been precisely fixed, and that for but one season of an abnormal year. Until the usual boundaries are defined with greater precision, the exceptional ones, such as those of 1925 when warm water reached as far south as central Chile, can be viewed with scant profit.

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BOTANY.—*Homonyms among names of trees and fossil plants.*[1]

ELBERT L. LITTLE, JR., U. S. Forest Service. (Communicated by WILLIAM A. DAYTON.)

The same names have sometimes been given independently both to species of living trees of the United States and to different species of fossil plants, but the number of homonyms of this type not previously corrected is relatively small. In the course of the preparation of a revised *Check list of the native and naturalized trees of the United States,* the accepted names have been checked against homonyms among fossil plants. Fortunately, only three changes in nomenclature have been necessary for the above publication, but additional names of tree species distinguished by some authors, as well as some names of fossils, are affected. It seems desirable to call attention to these homonyms among recent and fossil plants and to suggest that taxonomists working with living plants, and paleobotanists studying fossils, carefully compare their proposed new names before publication with the indexes of both groups, in order to avoid preoccupied names.

The International Rules of Botanical Nomenclature (ed. 3. 1935) apply to recent and fossil plants alike (art. 9), though a few special rules have been adopted for fossil plants. Nomenclature of fossil plants begins with the year 1820 (art. 20). A Latin diagnosis is not required for names of new groups of fossil plants (art. 38), but after January 1, 1912, names of new groups of fossil plants must be accompanied by illustrations (which serve as substitutes for duplicate specimens) in addition to the descriptions, or by references to earlier illustrations (art. 39). The rule about homonyms was changed in 1930 to reject a later homonym even if the earlier homonym is a synonym and not in use (arts. 60 (3) and 61). As a result of the change, some homonyms previously correctly used suddenly became invalid. Also, since specific epithets long abandoned as synonyms can never be used again in the same genus, there is now a greater possibility of making unintentional homonyms in large genera of woody plants having both living and extinct species.

Names of recent plants are well indexed in standard references, such as *Index Kewensis* and its supplements and the *Gray Herbarium card-index.* Fossil plants, however, are not so thoroughly cataloged. A detailed catalog of names of fossil plants of the world, *Fossilium catalogus II: Plantae,* edited by Jongmans[2] is in progress. Most of the 24 parts issued since the work was begun in 1913 are about extinct groups. The following parts, however, cover seven important families of recent woody plants and should be consulted by taxonomists making new names in these groups: Pars 6, Juglandaceae (1915); pars 8, Betulaceae (1916); pars 10, Ulmaceae (1922); pars 14, Sapindaceae (1928); pars 20, Anacardiaceae (1935); pars 23, Cornaceae (1938); and pars 24, Vitaceae (1939). Additional parts of interest also to students of recent plants are: Pars 13, Muscineae (1927); pars 17, Dicotyledones (ligna), or fossil wood (1931); and pars 19, Charophyta (1933).

In 1919 Knowlton[3] published a catalog of the Mesozoic and Cenozoic plants of North America known at that time, which should be consulted by taxonomists making new names in genera such as woody plants also represented as fossils. All affected fossil names that were known to be later homonyms of recent species were corrected by

[1] Received February 4, 1943.

[2] JONGMANS, W., ed., *Fossilium Catalogus II: Plantae,* pts. 1–24. 's-Gravenhage, 1913–1939.

[3] KNOWLTON, F. H., *A catalogue of the Mesozoic and Cenozoic plants of North America.* U. S. Geol. Surv. Bull. 696, 815 pp. 1919.

Knowlton and Cockerell in Knowlton's catalog (p. 11). This catalog, however, did not cover fossils outside North America, names published after 1919, or Paleozoic fossils, though Paleozoic fossils are in extinct genera. The United States Geological Survey, Washington, D. C., has an unpublished card catalog of names of fossil plants throughout the Plant Kingdom up to the year 1933, when compilation was discontinued. This valuable and detailed card catalog is located in the division of paleontology, United States National Museum. The homonyms mentioned here are among those detected when the accepted names of native and naturalized trees of the United States were checked against names of fossils in the paleobotanical card catalog. Most of these homonyms concern European fossils, especially names published before *Index Kewensis*, and a few names appearing since Knowlton's catalog.

The three changes in nomenclature from that of Sudworth's check list required because the names were used previously for fossils are summarized below.

Ilex amelanchier M. A. Curt.
SERVICEBERRY HOLLY

Prinos dubius G. Don, Gen. Syst. Gard. Bot. **2**: 20. 1832.

Ilex amelanchier M. A. Curt. ex Chapm., Fl. South. U. S. 270. 1860.

Ilex dubia (G. Don) B. S. P., Prelim. Cat. Anth. Pter. New York 11. 1888. Not *Ilex dubia* Weber, Palaeontographica **2**: 203, pl. 22, fig. 9. 1851 (fossil, Oligocene, Prussia).

Fernald (Rhodora **41**: 424–429, pl. 559. 1939) showed by examining the type that *Ilex dubia* (G. Don) B. S. P. is the same as *Ilex amelanchier* M. A. Curt. and so took up the former name. However, as *Ilex dubia* (G. Don) B. S. P. is a later homonym of a fossil, the name *Ilex amelanchier* M. A. Curt. should be restored. This shrubby species of the Coastal Plain from New Jersey to Georgia and Louisiana becomes a small tree according to Small (Man. Southeast. Fl. 1502. 1933) and will be added to the check list.

× **Quercus burnetensis** Little BURNET OAK

Quercus macrocarpa Michx. ×*Quercus virginiana* Mill.

× *Quercus coloradensis* Ashe, Bull. Torrey Bot. Club **49**: 268. 1922. Not *Quercus coloradensis* Lesq., Bull. Mus. Comp. Zool. **16**: 46. 1888 (fossil, Eocene, Colorado).

× *Quercus burnetensis* Little, Journ. Washington Acad. Sci. **33**: 9. 1943.

× **Quercus filialis** Little VARILEAF OAK

Quercus phellos L. × *Quercus velutina* Lam.

×*Quercus inaequalis* Palmer & Steyermark, Missouri Bot. Gard. Ann. **22**: 521. 1935. Not *Quercus inaequalis* Watelet, Descr. Pl. Foss. Bass. Paris 136, pl. 35, fig. 8. 1866 (fossil, Eocene, France).

× *Quercus filialis* Little, Journ. Washington Acad. Sci. **33**: 10. 1943.

The two earlier fossil homonyms of *Salix lancifolia* indicated below do not invalidate the name when transferred to a variety. The variety stands as a new name, rather than a new combination (art. 16), and Andersson is not cited as original author. The same epithet may be used as a species and variety (art. 29).

Salix lasiandra Benth. var. **lancifolia** Bebb
PACIFIC GRAY WILLOW

Salix lancifolia Anderss., Svenska Vet.-Akad. Handl. **6**: 34, pl. 2, fig. 23. 1867. Not *Salix lancifolia* A. Braun, Neues Jahrb. Mineral. Geogn. Geol. Petref. 1845: 170. 1845 (fossil, Miocene, Switzerland); A. Braun ex Unger, Gen. Sp. Foss. Pl. 419. 1850. Not *Salix lancifolia* Ludw., Palaeontographica **5**: 157, pl. 35, fig. 9. 1858 (fossil, Miocene, Hesse).

Salix lasiandra Benth. var. *lancifolia* Bebb in S. Wats., Bot. California **2**: 84. 1879.

Names for several tree species recognized by some authors but not accepted in the check list are invalid as later homonyms of fossils. These include a recently described species of *Abies*, an older species of *Acer*, a new species of *Quercus*, and three hybrids of *Quercus*. Doubtless additional homonyms occur among the names of exotic and culti-

vated trees, which have not been checked. *Juglans sieboldiana* will serve as an example.

Abies balsamea (L.) Mill. var. **phanerolepis** Fern. BRACTED BALSAM FIR

Abies balsamea (L.) Mill. var. *phanerolepis* Fern., Rhodora **11**: 203. 1909.

Abies intermedia Fulling, Journ. Southern Appalachian Bot. Club **1**: 93, fig. 1. 1936. Not *Abies intermedia* Saporta, Compt. Rend. Acad. Sci. Paris **94**: 1021. 1882 (fossil, Pliocene, France).

Acer rubrum L. RED MAPLE

Acer rubrum L., Sp. Pl. 1055. 1753.

Acer stenocarpum Britton in Britton and Shafer, North American Trees 647, fig. 598. 1908. Not *Acer stenocarpum* Ettinghausen, Denkschr. Bayer. Akad. Wiss. München **50**: 20, pl. 31, figs. 10–12. 1885 (fossil, Miocene, Carniola).

Further study is needed to determine whether *Quercus grandidentata* Ewan (Bull. Torrey Bot. Club. **64**: 512. 1937) is distinct. It was described from a few collections at Monrovia, Los Angeles County, Calif.; it is closely related to *Quercus engelmanni* Greene; and it may be a hybrid between *Quercus dumosa* Nutt. and *Quercus engelmanni* Greene. Also, the name is a homonym of *Quercus grandidentata* Unger (Gen. Spec. Pl. Foss. 401. 1850; fossil, Miocene, Galicia).

Another new species, *Quercus robusta* C. H. Muller (Torreya **34**: 119. 1934), known only from Oak Canyon, Chisos Mountains, Tex., is not affected because the earlier homonym, *Quercus robusta* Schulze (Zeitschr. für Naturw. **60**: 457. 1887; fossil, Upper Cretaceous, Baden), upon examination was found to be a *nomen nudum* (arts. 44, 45).

The name × *Quercus dubia* Ashe (Journ. Elisha Mitchell Sci. Soc. **11**: 93. 1894) should be abandoned as a name of uncertain identity as to its supposed parents and as a later homonym. Earlier homonyms are *Quercus dubia* Alm. in L. (Pl. Surinam. 15. 1775) and the fossil *Quercus dubia* Newberry (Ann. New York Lyc. Nat. Hist. **9**: 31. 1868; *nomen nudum;* fossil, Miocene, Montana); *Quercus dubia* Newberry [Proc. U. S. Nat. Mus. **5**: 506. 1883 (fossil; Miocene, Montana)]. The name of the fossil species was changed to *Quercus asymmetrica* Trel. (Mem. Nat. Acad. Sci. **20**: 28, pl. 12, fig. 10. 1924).

× **Quercus ludoviciana** Sarg. ST. LANDRY OAK

× *Quercus ludoviciana* Sarg., Trees and Shrubs **2**: 223. 1913.

× *Quercus subfalcata* Trel., Proc. Amer. Phil. Soc. **56**: 52. 1917. Not *Quercus subfalcata* Göppert, Tert. Fl. Insel Java 114. 1854. (*nomen nudum;* fossil, Miocene, Bohemia). Not *Quercus subfalcata* Friedrich, Geol. Specialk. Preuss. Abh. **4** (3): 257, pl. 9, figs. 4, 5. 1883 (fossil, Oligocene, Saxony).

× *Quercus ludoviciana* var. *subfalcata* (Trel.) Rehd., Journ. Arnold Arb. **7**: 240. 1926.

× *Quercus ludoviciana* Sarg. is the hybrid between *Quercus falcata* var. *pagodaefolia* Elliott and *Quercus phellos* L. × *Quercus subfalcata* Trel. is the hybrid between *Quercus falcata* Michx. and *Quercus phellos* L., and is a later homonym of a fossil. Rehder, under article 34, reduced the latter hybrid to a variety, and it seems simpler to group all the hybrids between two species, including hybrids of their varieties, all under the same name.

The relationships of × *Quercus venulosa* Ashe (Journ. Elisha Mitchell Sci. Soc. **41**: 268. 1926), described from Okaloosa County, Fla., are uncertain. Its supposed parents were *Quercus cinerea* Michx. and *Quercus caput-rivuli* Ashe, the latter originally described as a doubtful hybrid and later reduced by its author to *Quercus arkansana caput-rivuli* (Ashe) Ashe. The earlier homonym is *Quercus venulosa* (Eichwald) Eichwald (Lethaea Rossica **2** (1): 63, pl. 3, fig. 11. 1865; fossil, Russia), originally described as *Credneria venulosa* Eichwald (1853).

Juglans ailantifolia Carr. SIEBOLD WALNUT

Juglans sieboldiana Maxim., Bull. Acad. Imper. Pétersb., sér. 3, **18**: 60. 1873. Not *Juglans sieboldiana* Göppert, Tert. Fl. Insel Java 154. 1854; *nomen nudum.* Not *Juglans sieboldiana* Göppert, Tert. Fl. Schossnitz Schles. 36, pl. 25, fig. 2. 1855 (fossil, Miocene, Silesia).

Juglans ailantifolia Carr., Rev. Hort. [Paris] **50**: 414, fig. 85–86. 1878.

It is unfortunate that the name *Juglans sieboldiana* Maxim., long in use for a species

from Japan cultivated in the United States, must be rejected because the name was given 18 years earlier to a fossil from Europe. According to Nagel (Foss. Cat. II: Plantae, pt. 6: 52. 1915), *Juglans sieboldiana* Göppert is a synonym of *J. acuminata* A. Br. A fossil variety of the Japanese species was named *Juglans sieboldiana* Maxim. *fossilis* Nath. (Svenska Vet.-Akad. Handl. **20** (2): 37, pl. 1, figs. 13–17, 18(?). 1883).

EXAMPLES OF DUPLICATE NAMES

An interesting example of a genus that was named among fossils before it was distinguished among living trees is *Sequoia* Endl. (Syn. Conif. 197. 1847). Though a species of living trees was named earlier *Taxodium sempervirens* Lamb. (Descr. Genus *Pinus* **2**: [24]. 1824), the genus was based upon three species of fossil cones and was published with illustrations as *Steinhauera* Presl in Sternberg (Versuch Geogn. —Bot. Darst. Fl. Vorwelt. 202 illus. 1838). The more familiar name *Sequoia* Endl. has been retained by making it a *nomen conservandum*, while the older synonym, *Steinhauera* Presl, is a *nomen rejiciendum* (art. 21).

Various illustrations of homonyms that have been replaced could be cited. For example, *Juglans californica* S. Wats. (Proc. Amer. Acad. Arts Sci. **10**: 349. 1875) appeared only three years before the fossil species, *Juglans californica* Lesq. (Mem. Mus. Comp. Zool. **6** (2): 34, pl. 9, fig. 14; pl. 10, fig. 23. 1878; Miocene, California). The latter was changed to *Juglans leonis* Cock. (Amer. Journ. Sci., ser. 4, **26**: 543. 1908). The Miocene fossil from Alaska, *Betula alaskana* Lesq. (Proc. U. S. Nat. Mus. **5**: 446, pl. 6, fig. 14. 1883) had priority over *Betula alaskana* Sarg. (Bot. Gaz. **31**: 236. 1901). When the earlier use of the name was called to his attention, Sargent renamed the living species *Betula neoalaskana* Sarg. (Journ. Arnold Arb. **3**: 206. 1922). However, this species has since been reduced to a variety, *Betula papyrifera* Marsh. var. *neoalaskana* (Sarg.) Raup (Contrib. Arnold Arb. **6**: 152. 1934).

Among the more recent cases that have not been corrected is the shrubby species *Sorbus alaskana* G. N. Jones (Journ. Arnold Arb. **20**: 24, pl. 226. 1939), a later homonym of the Upper Cretaceous fossil, *Sorbus alaskana* Hollick (U. S. Geol. Surv. Prof. Pap. 159: 97, pl. 74, fig. 1. 1930).

FOSSILS WITH NAMES PREOCCUPIED BY RECENT TREES

The names of several species of fossils are later homonyms of names in use for recent trees of the United States. The fossils are mostly old European species that may no longer be recognized. However, if they are valid and distinct species still in the same genera and if they have not already been changed, they should be given new names by specialists familiar with them. Some of these preoccupied names of fossils that may not have been corrected are given below:

Magnolia macrophylla Vukotinovića, Jugoslav. Akad. Zagreb Rad **13**: 202. 1870 (fossil, Miocene, Croatia). Not *Magnolia macrophylla* Michx., Fl. Bor.-Amer. **1**: 327. 1803.

Pinus resinosa Ludwig, Palaeontographica **5**: 87, pl. 18, figs. 3–4. 1857 (fossil, Miocene, Hesse). Not *Pinus resinosa* Ait., Hort. Kew. **3**: 367. 1789.

Pinus rigida (Göppert and Berendt) Schimper, Traité Paléont. Végét. **2**: 291. 1870 (fossil, Miocene, Prussia; originally in genus *Piniles*). In making this combination, Schimper remarked that there already existed a *Pinus rigida* Mill. Not *Pinus rigida* Mill., Gard. Dict. ed. 8, *Pinus* No. 10. 1768.

Populus tremuloides Massalongo, Piante Foss. Terz. Vicentino 146. 1851 (fossil, Miocene, Italy). *Populus tremuloides* Wessel in Wessel and Weber, Palaeontographica **4**: pl. 24, fig. 2. 1855 (*nomen nudum;* fossil, Miocene, Prussia). Not *Populus tremuloides* Michx., Fl. Bor.-Amer. **2**: 243. 1803.

Quercus reticulata (Eichwald) Eichwald, Lethaea Rossica **2** (1): 62, pl. 3, fig. 16. 1865 (fossil, Cretaceous, Russia; originally *Credneria reticulata* Eichwald (1853)). Not *Quercus reticulata* Humb. and Bonpl., Pl. Aequin. **2**: 20, pl. 86. 1809.

Rhus microphylla Heer, Svenska Vet.-Akad. Öfv. Forh. **28**: 1184. 1871 (*nomen nudum*); Svenska Vet.-Akad. Handl. **12**: 117, pl. 32, fig. 18. 1874 (fossil, Cretaceous, Greenland). Not *Rhus microphylla* Engelm. ex A. Gray, Smithsonian Contr. Knowl. **3** (5) (Pl. Wright. 1): 31. 1852.

The following fossil homonym has been reduced to synonymy:

Quercus obtusa Knowlton, U. S. Geol. Surv. Prof. Pap. 140: 38, pl. 22, fig. 8. 1926. (fossil, Miocene, Washington). Made a synonym of *Quercus simulata* Knowlton by Brown (U. S. Geol. Surv. Prof. Pap. 186-J: 173. 1937). Not *Quercus obtusa* (Willd.) Ashe, Torreya **18**: 72. 1918.

Though no check was made of homonyms among fossils and synonyms of recent trees of the United States, as these names would not affect the nomenclature of the check list or cause any confusion, a few later homonyms of this type were found among the fossils. An example is *Abies mucronata* (Göppert and Menge) Göppert (Schles. Ges. Vaterl. Kult. Jahresb. **48** (1870): 55. 1871; originally described in the genus *Abietites*). Not *Abies mucronata* Raf. (Atl. Journ. 120. 1832), the name upon which was based *Pseudotsuga mucronata* (Raf.) Sudw., a synonym of *Pseudotsuga taxifolia* (Poir.) Britton.

SIMILAR BUT NOT IDENTICAL NAMES

Some names of fossils and recent plants which are similar but fortunately differ slightly in spelling may be retained without confusion as distinct names (art. 70), though possibly a few might be considered orthographic variants. A partial list of these similar names follows.

FOSSIL PLANTS	RECENT PLANTS
Acer grosse-dentatum Heer (1859)	*Acer grandidentatum* Nutt. ex. Torr. and Gray (1838)
Crataegus holmesii Lesq. (1887)	*Crataegus holmesiana* Ashe (1900)
Fraxinus oregonensis Knowlton and Cockerell (1919)	*Fraxinus oregona* Nutt. (1849)
Juglans quadrangula Ludwig (1857)	× *Juglans quadrangulata* (Carr.) Rehd. (1900)
Pinus quadrifoliata Peola (1900)	*Pinus quadrifolia* Parl. ex Sudw. (1897)
Quercus neomexicana Knowlton (1918)	*Quercus novomexicana* (A. DC.) Rydb. (1901)
Quercus treleasii Berry (1928)	*Quercus treleaseana* A. Camus (1932)

GENERIC HOMONYMS

Apparently no generic names of living trees of the United States are later homonyms of fossil genera. However, an unimportant example of a generic name used independently in living and fossil plants is *Batodendron* Nutt. (Trans. Amer. Phil. Soc., ser. 2, **8**: 261. 1843), a segregate of *Vaccinium* L., generally not used by conservative workers. The name *Batodendron* Landsborough (Ann. Mag. Nat. Hist. **13**: 290. 1844) was given a year later to a Paleozoic fossil from Scotland inadequately described without specific name. An Upper Devonian fossil from Siberia was named *Batodendron* sp. Chachloff (1921).

If a detailed check of extinct genera were made with indexes of generic names of living plants, it is likely that a few homonyms would be found. Of course, if the older name is rejected as a synonym and is no longer in use, the later homonym can be retained without confusion merely by making it a *nomen conservandum* (art. 21).

An example of a generic name in use in both groups is *Berrya*. *Berria* Roxb. (Pl. Corom. **3**: 60, pl. 264. 1819; usually spelled *Berrya*, an orthographic variant by DC., Prodr. 1. 517. 1824) is a genus of one or two species of Tiliaceae. *Berrya* Knowlton (U. S. Geol. Surv. Prof. Pap. 155: 133, pl. 41, fig. 4–5. 1930), a fossil genus of uncertain position with one species, is a later homonym. This has been synonymized with *Cercidiphyllum* by Brown (Journ. Pal. **13**: 492. 1939).

AVOIDANCE OF HOMONYMS

A few suggestions for avoiding the creation of additional, unnecessary homonyms among recent and fossil plants may be drawn from the examples given. Of course, persons proposing new specific names in genera having both living and extinct species, especially large genera of woody plants such as *Quercus*, should check their tentative names in the best available indexes and catalogs of both groups. Additional published catalogs or indexes of fossil plants are urgently needed by taxonomists of living plants as well as by paleo-

botanists. Schopf[4] has recently called attention to the desirability of continued compilation and publication of additions to the existing catalogs of American fossil plants.

Certain epithets are much more likely to be used independently for fossil and recent plants than others. Names derived from large geographical areas, such as Alaska and the States, are often repeated, but many fossils are named from a small locality where the types were collected or from the geological formation without risk of duplication. Epithets of obvious descriptive characters among certain species within a large genus containing both living and extinct species have a relatively high probability of being homonyms. Names suggesting resemblance to another species or indicating intermediate or uncertain characters may have been used before for fossils also.

As long as the number of homonyms among recent and fossil plants remains rather small, the problem is not serious, and possibilities of confusion at present are slight. If the number of homonyms among the two groups should ever be greatly increased at some future date when many more species of fossils are known, possibly the same epithets could be permitted for both recent and fossil species. Most specialists do not work with both groups anyway. The greatest sources for error then would be in recent species found also as fossils in the geologically youngest deposits, such as Pleistocene. Identical names for plants and animals are permitted (art. 6), though the names repeated are mostly genera. Another possible solution would be to assign slightly different generic names to fossils that are closely related to living genera. Then the same specific epithets could be repeated in both. To some extent this practice has been followed by the use of suffixes, such as *-ites*, and *-oxylon*, and *-phyllum* in the examples *Pinites* from *Pinus*, *Araucarioxylon* from *Araucaria*, and *Sapindophyllum* from *Sapindus*.

[4] SCHOPF, JAMES M., *American Committee on Paleobotanical Nomenclature.* Chronica Bot. 7: 226–227. 1942.

BOTANY.—*New grasses from the Philippines and South India.*[1] JOSÉ VERA SANTOS, Botanical Gardens, University of Michigan. (Communicated by AGNES CHASE.)

During the progress of a study on the *Genera of Philippine grasses*, Asiatic specimens of *Garnotia*, *Isachne*, and *Sacciolepis* were found in the United States National Herbarium that were either without or with doubtful determinations. Among them is the material hitherto generally referred to *Garnotia stricta* Brongn.[2] At the suggestion of Mrs. Agnes Chase, studies were undertaken on the distinguishing characters of the true *Garnotia stricta* Brongn., and a comparison was made with the material formerly referred to this species. The result of this investigation led to the examination of the species of *Garnotia* and the description of a new species. The writer is greatly indebted to Mrs. Chase, for her technical assistance in the preparation of this paper, and to Dr. Elzada U. Clover, for going over the manuscript.

Garnotia mindanaensis Santos, sp. nov.

Perennis, 45–55 cm alta; culmi caespitosi, erecti, simplices, nodiis pubescentibus; vaginae glabrae, collari pubescenti et venis prominentibus; ligulae 0.2 mm longae, glabrae; laminae lineari-lanceolatae, planae, 8–25 cm longae, 4–6 mm latae; paniculae 10–18 cm longae, angustae interruptae; spiculae 4–4.5 mm longae, 0.5–0.6 mm latae, anguste lanceolatae, e dorso compressae; glumae subaequales, breviter aristatae, 3-nerves, scabrae; lemma maturum glumas aequans, lanceolatum, glabrum, 3-nerve; arista lemmate 1–2.5 plo longior; palea anguste lanceolata, membranacea, marginibus supra auriculas molliter pubescentibus; lodiculae 2, minutae, spatulatae, glabrae.

[1] Received February 23, 1943. Papers from the Department of Botany of the University of Michigan, no. 820. Read before the 48th meeting of the Michigan Academy of Science, Arts and Letters held at the University of Michigan, Ann Arbor, Mich., March 26–27, 1943.

[2] In DUPERREY, M. L. I., *Voyage autour du monde* 2[1]: 133–134, pl. 21. 1830.

Plants perennial, 45–55 cm tall; culms simple, tufted, erect or slightly geniculate toward the base, the nodes pubescent; sheaths glabrous, the collar pubescent, the veins prominent; ligules about 0.2 mm long, glabrous, the margin erose; blades linear-lanceolate, flat, 8–25 cm long, 4–6 mm wide, narrowed at the base, glabrous on both surfaces except for a few hairs toward the tip and the pubescence, sometimes with long hairs intermixed, above the ligule, the margins antrorsely scabrous; panicles 10–18 cm long, narrow, interrupted, the branches loosely appressed; spikelets about 4–4.5 mm long, 0.5–0.6 mm wide, narrowly lanceolate, dorsally compressed, with short hairs at the base, in pairs, the members of each pair with short unequal pedicels; glumes subequal, both 3-nerved, the nerves scabrous, the middle one exerted into a short awn, the internerves glabrous; lemma at maturity equaling the glumes, lanceolate, glabrous, 3-nerved, the acute tip extending into an awn about 1–2.5 times as long as the lemma; palea narrowly lanceolate, membranaceous, enclosing a perfect flower, keeled on the back along the two lateral nerves, the margins auricled toward the base, softly pubescent from above the auricles to the tip; lodicules two, minute, spatulate, glabrous.

The type is in the herbarium of the University of Michigan, duplicate type in the U. S. National Herbarium, collected by H. H. Bartlett, no. 17235, December 6, 1940, grassland at Del Monte, Bukidnon, Mindanao Island, Philippines.

This species shows some resemblance to *Garnotia stricta* Brongn., the type species of the genus, and different collections have been referred to it. In view of this fact, a thorough study was made of the characteristics of the real *Garnotia stricta* Brongn. as proposed in 1830. Since the type specimen, which came from "Ile de Taiti," is not available, Brongniart's original description and the accompanying illustration showing the awnless lemma (pl. 21) are the only authentic bases for determining the identity of this species. The species here proposed differs from *Garnotia stricta* Brongn. in the absence of a rhizome, in the glabrous ligule, short-awned second glume, long-awned lemma, soft pubescence of the margin of the palea from above the auricles to the tip, and in the glabrous lodicules.

Sacciolepis glabra Santos, sp. nov.

Annua, 40–55 cm alta; culmi graciles, erecti vel decumbentes, nodiis inferioribus radicantes; vaginae glabrae; ligulae membranaceae, 0.5 mm longae, marginibus pilosis; laminae lineares 5–12 cm longae, 3–5 mm latae, supra sparse papilloso-pilosae, marginibus scaberulis; paniculae maturae contractae, spiciformes, cylindricae, ca 2–5 cm longae, 7 mm latae; spiculae 3–4 mm longae, glabrae, a latere compressae, oblongo-lanceolatae; gluma prima quam spicula ca 3 plo brevior, subacuta, 3–5-nervis, marginibus hyalinis; gluma secunda et lemma vacuum aequalia, 11-nervia, illa gibbosa hoc basi saccatum; palea sterilis reducta; lemma fertile quam spicula ca 2 plo brevius, lanceolato-ellipticum; palea lemma aequans, utraque obscure nervosa; granum oblongo-ellipticum, subfuscum.

Plants annual, 40–55 cm tall; culms glabrous, slender, branched, erect to decumbent, rooting at the lower nodes; sheaths glabrous, slightly compressed; ligules membranous, 0.5 mm long, the margin pilose; blades linear, the tips acute, 5–12 cm long, 3–5 mm wide, the upper ones much longer than the lower, the upper surface sparsely papillose-pilose, the margins scaberulous; mature panicles contracted, spikelike, cylindric, about 2.5 cm long, 7 mm wide; spikelets 3–4 mm long, glabrous, crowded, solitary to subfascicled, laterally compressed, oblong-lanceolate in dorsal view; first glume about ½ as long as the spikelet, subacute, 3- to 5-nerved, the margin hyaline; second glume and empty lemma equal, both 11-nerved, the glume strongly gibbose below, the lemma more or less straight for the greater part of its length except for the saccate base; sterile palea reduced; fertile lemma about one-half as long as the spikelet, lanceolate-elliptic, pale, shining, the tip acute; palea as long as the lemma, both obscurely nerved, chartaceous-indurate; grain light brown, oblong-elliptic.

The type is in the herbarium of the University of Michigan, duplicate type in the U. S. National Herbarium, collected by L. E. Ebalo, no. 174, October 26–30, 1939, at Wawan and Dimaraga Mountains, Mansalay, Island of Mindoro, Philippines.

This species shows some relation to two Asiatic grasses, *Sacciolepis contracta* (Wight &

Fig. 1.—*Garnotia mindanaensis:* Habit sketch of the flowering plant, ×⅓. *a*, Side view of the spikelet; *b*, first glume; *c*, second glume; *d*, fertile lemma; *e*, palea with the bisexual flower. *a–e*, ×10. (Type.)

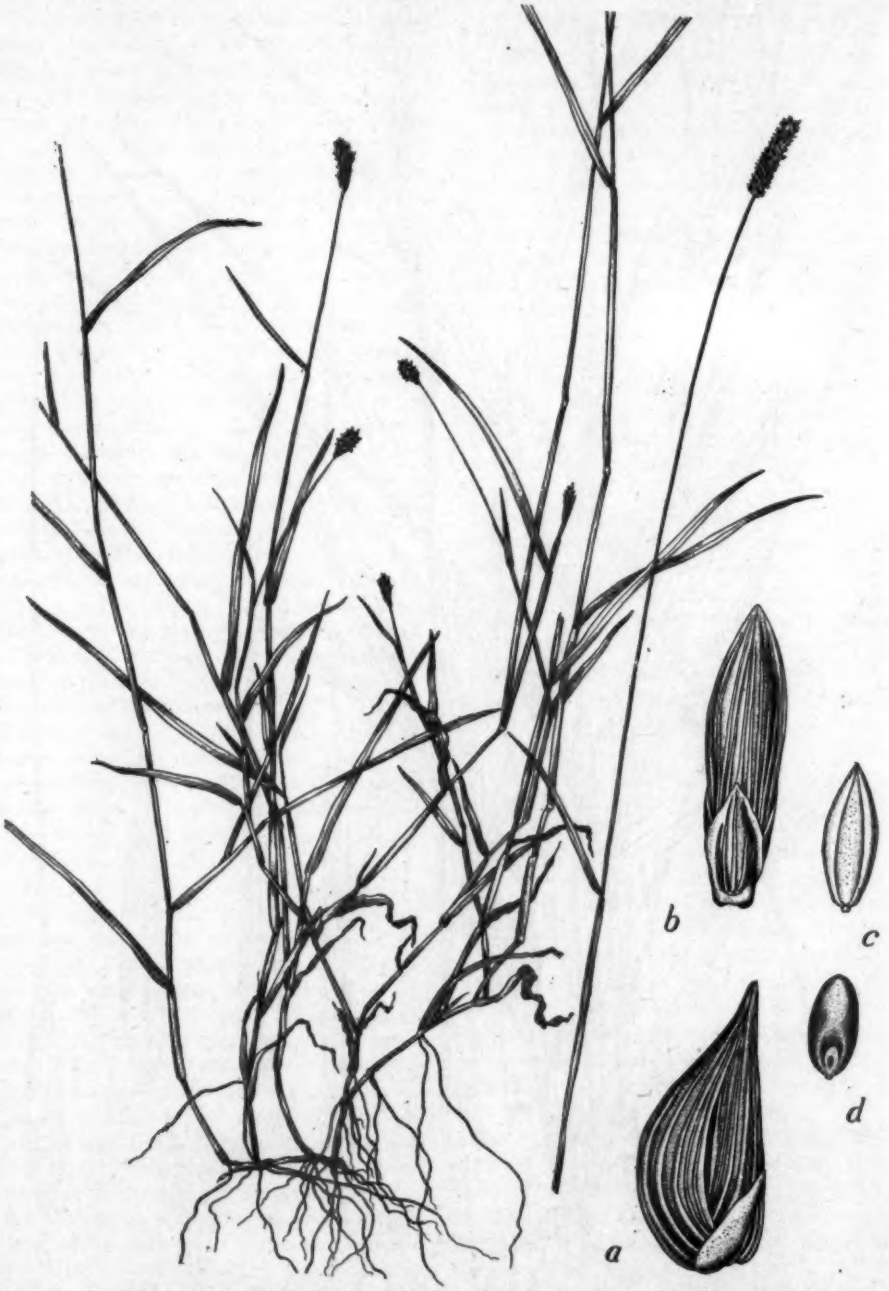

Fig. 2.—*Sacciolepis glabra:* Habit sketch of the flowering plant, ×⅓. *a* and *b*, Side and dorsal views of the spikelet, respectively; *c*, fertile lemma; *d*, grain. *a*–*d*, ×10. (Type.)

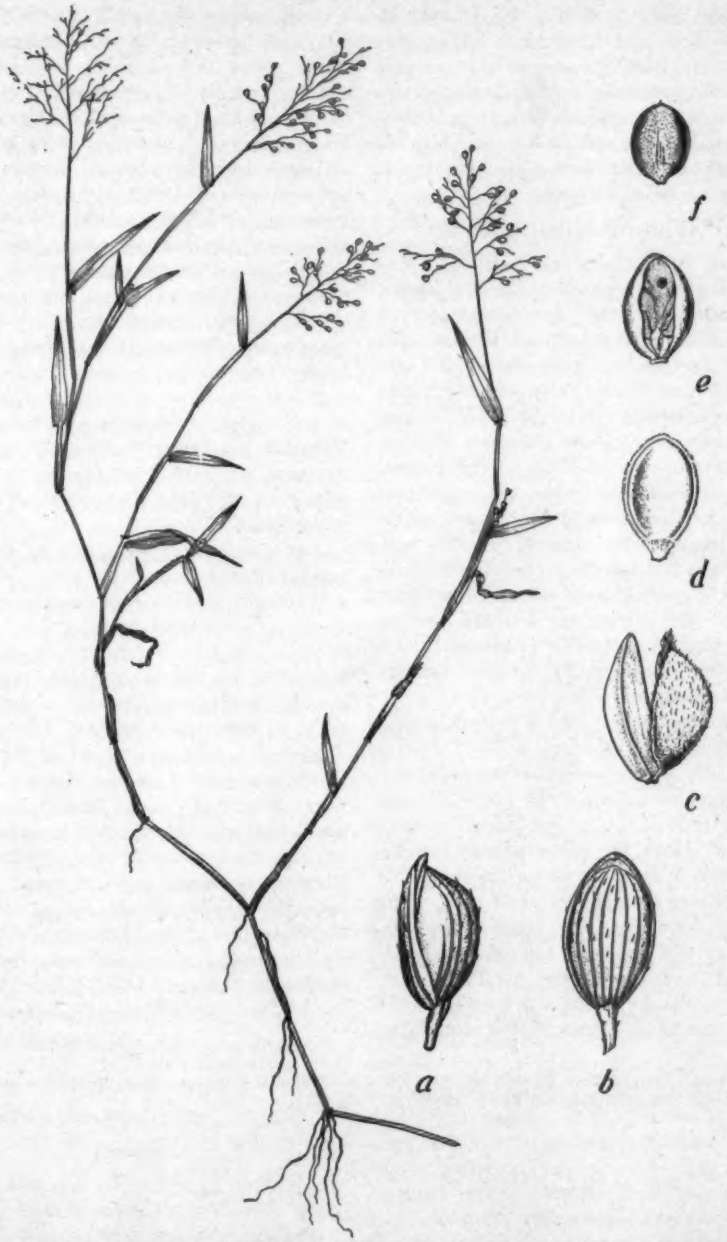

Fig. 3.—*Isachne lutaria:* Habit sketch of the flowering plant, ×½. *a* and *b*, Side and dorsal views of the spikelet, respectively; *c*, side view of the lower and upper lemmas; *d*, ventral view of the upper lemma; *e*, palea of the upper lemma enclosing the pistil, filaments, and lodicules; *f*, grain. *a–f*, ×10. (Type.)

Arn.) Hitchc.[3] and *S. indica* (L.) Chase.[4] It differs from both in having much larger, glabrous spikelets; from *S. contracta* in its annual character, the decumbent culms, rooting at the lower nodes, the lax, sparsely pubescent blades, and shorter panicles; and from *S. indica* in its much taller habit and in the panicles, which are more than twice as long.

Isachne lutaria Santos, sp. nov.

Annua, ca. 30 cm alta; culmi graciles, adscendentes, ramosi, nodiis pubescentibus vel pilosis, eis inferioribus radicantibus; vaginae glabrae vel marginibus ciliatae; ligulae ciliatae pilis longis albidis; laminae lanceolatae, 2–4 cm longae, 3–5 mm latae, venis et marginibus scaberulis; paniculae ovatae, 3–5 cm longae, 2.5–4 cm latae, ramis flexuosis non glandulosis; spiculae elliptico-oblongae, 1.5–1.7 mm longae, 1–1.2 mm latae; glumae subaequales spiculam subaequantes, 9-nerves, late obtusae, sparse hispidae; lemma floris masculi spiculam subaequans, membranaceum, obscure 5-nerve; lemma fertile quam spicula clare brevius, chartaceum, breviter stipitatum, obscure 5-nerve, dorso et marginibus tenuiter pubescens; palea quam lemma paulo brevior, glabra; granum orbicularo-oblongum.

Plants annual, about 30 cm tall; culms ascending, slender, branched, rooting at the lower nodes, slightly compressed, the internodes glabrous, the nodes pubescent to pilose; sheaths loose, shorter than the internodes, glabrous or the margins ciliate, the cilia gradually increasing in length toward the pilose upper portion and continuous with the fringe of long, white hairs which form the ligule; blades lanceolate, 2–4 cm long, 3–5 mm wide, the veins and margins scaberulous, the auricles papillose-pilose; panicles ovate, 3–5 cm long, 2.5–4 cm wide, the branches spreading, flexuous, nonglandular; spikelets elliptic-oblong, 1.5–1.7 mm long, 1–1.2 mm wide, greenish to purplish; glumes subequal, about as long as the spikelet, both 9-nerved, broadly obtuse, sparsely hispidulous, the second more prominently convex than the first; staminate lemma about as long as the spikelet, obscurely 5-nerved, membranous, its palea of the same length and texture, obscurely 2-nerved; fertile lemma distinctly shorter than the spikelet, chartaceous, short-stipitate, elliptic to elliptic-obovate, plano-convex, 5-nerved, finely pubescent on the back and margin; palea slightly shorter than the lemma, ovate to elliptic-ovate, glabrous, enclosing a perfect flower; grain brown, orbicular-oblong.

The type is in the herbarium of the University of Michigan, fragment of type in the U. S. National Herbarium, collected by E. W. Erlanson, no. 5190, January 8, 1934, at the edge of a paddy field, Trivandrum, Travancore, South India.

The specific epithet refers to the muddy habitat of this grass.

While the characters of this species agree in many respects with those of *Isachne globosa* (Thunb.) O. Kuntze,[5] it is distinguished from the latter by the smaller spikelets, sparsely hispidulous glumes, and the short-pubescent back of the upper lemma. *Isachne globosa* (Thunb.) O. Kuntze is based on *Milium globosum* Thunberg.[6] Lasègue[7] states that Thunberg's specimens are in Stockholm, Sweden, which indicates that the type is probably in the famous herbarium of the Naturhistoriska Riksmuseet. Since present world conditions make the type inaccessible for examination, the determination of the Thunberg species is based on his original description and the topotype collected by Hisauti (U. S. National Herbarium no. 1162864), July 1921, at Yokohama, Japan.

[3] Mem. B. P. Bishop Mus. **8**: 199, fig. 90. 1922.
[4] Proc. Biol. Soc. Washington **21**: 8. 1908.
[5] *Revisio genera plantarum* **2**: 778. 1891.
[6] *Flora Japonica* 49. 1784.
[7] *Musée botanique de A. Benjamin Delessert* 344. 1845.

PALEOBOTANY.—*A climbing fern from the Upper Cretaceous of Wyoming.*[1] ROLAND W. BROWN, U. S. Geological Survey.

The fern described here is, so far as I am aware, the first authentic Cretaceous and earliest known species of *Lygodium* from North America. I found these specimens in a small collection made on September 29, 1913, by V. H. Barnett and J. B. Reeside, Jr., of the United States Geological Survey, in sec. 6, T. 33 N., R. 78 W., on the bank of the North Platte River, 4 miles east of Casper, Wyo. On the 1925 Geological Map of Wyoming this locality is within the area designated as Pierre shale. Shaw's (1909, pl. 9) more detailed map, depicting the Glenrock coal field, differentiates the upper part of the Pierre shale as a sandy, shaly, coal-bearing sequence, in which this locality occupies a position near coal B, which overlies what is now called the Parkman sandstone member of the Mesaverde formation, a part of the Montana group of the Upper Cretaceous. The matrix containing these specimens is a gray shale with a tinge of pink, especially when wet.

The several floras embraced by the Mesaverde formation or group and its equivalents are much in need of critical study and correlation. At most localities in New Mexico and Colorado where the Mesaverde is well developed the formation has thus far proved relatively barren, but in the vicinity of Rock Springs, Wyo., some strata associated with coal seams yield particularly beautiful, well-preserved specimens of ferns, conifers, and dicotyledons.

Besides the new species of fern, the collection from Casper, Wyo., includes several other unidentified ferns and a few dicotyledonous leaf fragments.

SCHIZAEACEAE

Lygodium pumilum Brown, n. sp.

Figs. 1–5

Sterile pinnules of palmate outline, in pairs, 2 cm or less in width, generally with four lobes, which are of nearly even width throughout but may sometimes be slightly spatulate. Tips of the lobes broadly rounded. Margins obscurely toothed. Bases cuneate to rounded, but none cordate as in some living species. Petiolules short. Primary venation the result of two dichotomies, and secondary venation generally once-forked. No fertile pinnules were found.

Figs. 1–5.—*Lygodium pumilum* Brown, n. sp. Natural size.

This species has the smallest pinnules of any fossil *Lygodium* known, if one rejects the very doubtful form called *Lygodium? antiquorum* Shirley (1898, p. 17, pl. 17, fig. 3) from the early Mesozoic strata of Queensland, Australia. This is a 3-lobed specimen about one-fourth the size of the pinnules of *L. pumilum*. It was thought to be a fertile pinnule, but as illustrated it is only a tantalizing outline. Consequently, judgment regarding its true identity must be reserved.

Describing the Paleocene species, *Lygodium coloradense*, from the Dawson arkose in the Denver Basin of Colorado, F. H. Knowlton (1930, p. 30) discussed the living and fossil species of *Lygodium*. It appears that the only American Cretaceous species so far reported are *L. trichomanoides* Lesquereux from the Dakota sandstone of Kansas and *L. compactum* Lesquereux from the Laramie formation of Colorado. It was Knowlton's opinion, in which I concur, that these species, founded upon single fragments neither of which can be identified with cer-

[1] Published by permission of the Director, Geological Survey, U. S. Department of the Interior. Received March 22, 1943.

tainty, are of little or no value. They are examples of the unfortunate practice of attaching generic and specific labels to specimens with insufficient character to warrant such distinction, with the ultimate result of bringing paleobotany into disrepute. These two specimens should be and are hereby rejected as representing identifiable species of *Lygodium*. This leaves *L. pumilum* as the only known authentic American Cretaceous species. Its diminutiveness clearly separates it from the Tertiary species.

One authentic European species, *Lygodium cretaceum* Debey and Ettingshausen (1859, p. 198, pl. 2, figs. 18–21; pl. 3, fig. 28), said to be from the Senonian of Prussia, is represented by fertile and sterile foliage. The sporangia of this species occur on the margins of leafy pinnules, a habit shown by a number of living species.

Lygodium pumilum resembles no living species very closely, but apparently belongs in the group that includes *L. palmatum*, the climbing fern of the eastern United States. The latter, rather rare now because it was indiscriminately collected for decorative purposes before receiving legal protection, frequents moist thickets and open woods in lowlands but may sometimes be found at elevations exceeding 2,000 feet. Most of the 40 living species of *Lygodium* now listed are tropical or subtropical. They have a lithe, willowy attractiveness, and their dissected foliage displays great variation, which makes accurate identification of the species extremely difficult. The climbing portion above ground corresponds to the frond in nonclimbing ferns, and the foliage itself, both fertile and sterile, constitutes subdivisions of the frond, called pinnules by some and pinnae by others.

Considering that palms are also found in the Mesaverde formation, we may conjecture that *Lygodium pumilum* was a member of a floral assemblage adapted to a warmer, moister, less rigorous climate than that which prevails in Wyoming today.

I am grateful to Dr. William R. Maxon, of the National Museum, for the privilege of consultation with him during the preparation of this paper.

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ORNITHOLOGY.—*Description of a third form of curassow of the genus* Pauxi.[1]

ALEXANDER WETMORE, U. S. National Museum, and W. H. PHELPS, Caracas, Venezuela.

The genus *Pauxi* has been one of the least known of the interesting group of curassows in spite of the fact that the typical form was named by Linnaeus in 1766. The earliest specimens to come to the attention of students of birds apparently were obtained from Indians, and were attributed erroneously to Mexico, the Island of Curaçao, Cayenne, the upper Orinoco, and various other localities where the species is not known to exist. In 1870 Sclater and Salvin recorded *Pauxi* from near Caracas, and it was determined in the years that followed that these birds inhabited the forested mountain areas of northern Venezuela from near Caracas west to the vicinity of Mérida. Comparatively few specimens have been received in museums in the period since the latter part of the sixteenth century when Aldrovandus wrote of it under the name of the *Gallina indica alia*, until recently when its haunts have become better known. Unexpectedly, two were obtained recently by M. A. Carriker, Jr., for the Academy of Natural Sciences of Philadelphia, during work in Bolivia, in the hills above Bolívar, at 2,500 feet elevation near Palmar, in the Yungas de Cochabamba. These proved to have the casque rounded and conical instead of swollen and were described by Bond

[1] Received March 25, 1943.

and de Schauensee as *Pauxi unicornis*.[2]

From February to March, 1940, W. H. Phelps put an expedition in the field in the eastern slopes of the Sierra de Perijá, west of Machiques, in northwestern Venezuela. One of the collectors of the party purchased from Indians of the Manastara tribe living at La Sabana a necklace made of beads, with decorations in the form of three head scalps of *Pauxi* composed of the upper half of the bill, the casque, and the skin of the crown down to the eyes. The Indians reported a *pauji* in the adjacent forests, but none could be found during the course of the expedition. In 1942 a second necklace was received in Caracas as a gift with the assurance that it came from the Indians of the Machiques region. This second necklace was composed of beads, the bills, chest feathers, and humeri of two species of toucans, and six of the *Pauxi* scalps.

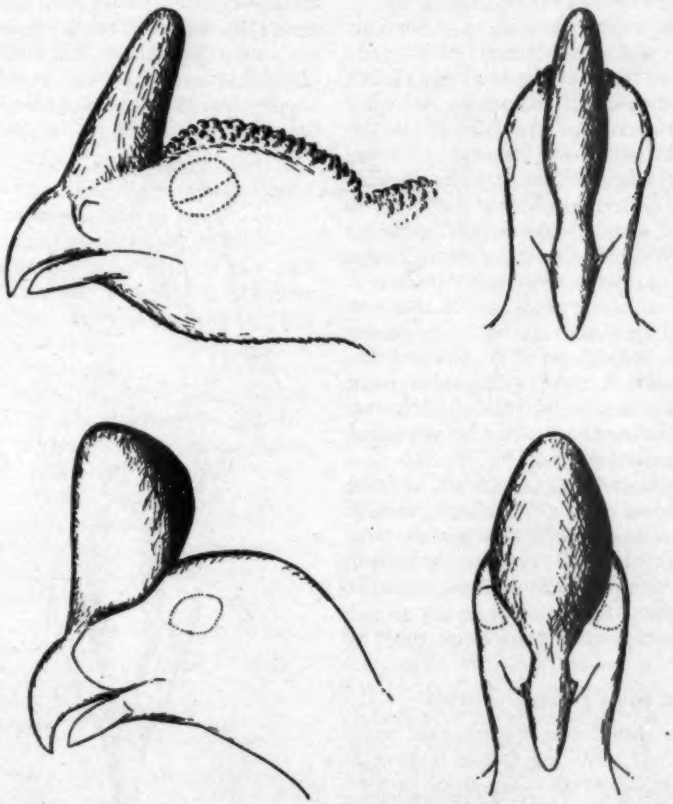


Fig. 1.—Head of *Pauxi p. unicornis* Bond and de Schauensee (above) and of *P. p. pauxi* (Linnaeus) one-half natural size, reproduced to scale, through the courtesy of J. S. Bond and R. M. de Schauensee.

In 1941 M. A. Carriker, Jr., collecting for the U. S. National Museum, following work with A. Wetmore through the Guajira, continued into the Sierra Negra at the northern end of the Perijá range on the Colombian side of the mountains. In this

[2] *Pauxi unicornis* Bond and de Schauensee, Notulae Naturae Acad. Nat. Sci. Philadelphia, no. 29: 1. Oct. 24, 1939.

work he secured five fine skins of *Pauxi*, a male at 1,800 feet near El Bosque back of Carriapia on June 21, a male at 1,200 to 1,500 feet near Tierra Nueva, July 21, and two adult females and one juvenile between 4,000 and 4,500 feet near Monte Elias in the same general region on August 9 and 11.

In Caracas, on comparing the scalps from the necklaces with skins from farther east in Venezuela, it was evident at once that an unknown form was concerned. After comparison there, through the kindness of Dr. William Beebe, six of the scalps, showing the variations in form, were brought to the American Museum of Natural History, where E. Thomas Gilliard made further studies with material available there and in Philadelphia, assembling much valuable information. When the series of skins in the National Museum came to his attention it seemed desirable to select one of those as type rather than one of the fragmentary heads as was first intended. As Gilliard was under necessity of undertaking other work that has taken him out of the United States, we are completing the study with the aid of additional material.

The investigation has been much assisted by the kindness of Miss Jocelyn Crane, of the Department of Tropical Research, New York Zoological Society, in photographing in Caracas the nine heads obtained from the Indian necklaces.

The hitherto unknown form may be known as—

Pauxi pauxi gilliardi, n. subsp.

Characters.—Similar to *Pauxi pauxi pauxi* (Linnaeus)[3] but with the frontal casque or helmet smaller, less swollen (Fig. 2); bill smaller.

Description.—Type, U.S.N.M. 368540, from 1,200 to 1,500 feet elevation near Tierra Nueva, at the northern end of the Serranía de Valledupar, or Sierra Negra, slightly south of east of Fonseca, Departamento de Magdalena, Colombia. Abdomen, extreme lower breast, under tail-coverts, and tip of tail white; rest of plumage black; feathers of head and upper neck, short, thick and soft to the touch, those surrounding the eye being very small; foreneck, breast, and sides with a greenish sheen, with each feather bordered distally with clear black, producing a dull, squamated appearance that is most prominent on the upper breast and foreneck; exposed feathers of dorsal surface, including wings and tail, also with a dull greenish cast with the wing coverts, lower hind neck, upper back, and longer upper tail-coverts margined narrowly with deep black to produce somewhat indistinct squamations; lower back and rump dull black. Bill dull red; casque blackish brown, with a wash of dull silvery gray on distal third; tarsi and toes dull reddish brown; claws blackish brown (from dried skin).

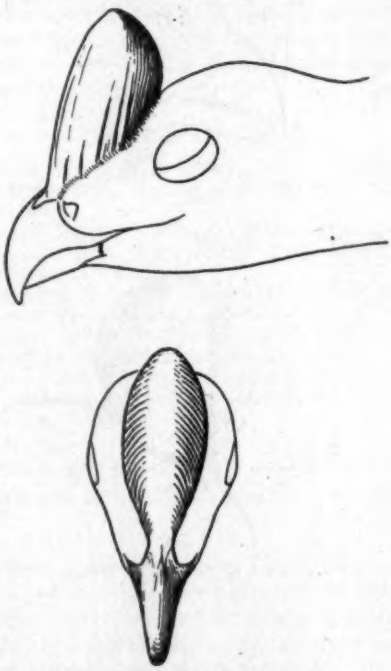


Fig. 2.—Head of *Pauxi p. gilliardi*, one-half natural size.

Measurements.—Males, 2 specimens, wing 354, 370, tail 305, 317, culmen from base of casque 32.1, 33.7, tarsus 110.3–112.1, length of casque (casque deformed in one bird) 58.3, width of casque 24.1, depth of casque 24.5, greatest circumference of casque 76 mm.

Females, 2 specimens, wing 336, 352, tail 290, 292, culmen from base of casque 30.4, 30.7,

[3] *Crax pauxi* Linnaeus, Systema naturae, ed. 12, 1: 270. 1766.

tarsus 102.9, 103, length of casque 53.5, 57.8, width of casque 23.9, 27, depth of casque 24, 27.1, greatest circumference of casque 76, 83 mm.

Type, male, wing 354, tail 305, culmen from casque 32.1, tarsus 110.3, length of casque 58.3, width of casque 24.1, depth of casque 24.5, greatest circumference of casque 76 mm.

Range.—Known from the mountain forests of the northern part of the Sierra de Perijá from 1,200 to at least 4,500 feet elevation from the region east of Fonseca, Magdalena, Colombia, around to the headwaters of the Río Negro above Machiques, Zulia, Venezuela.

Remarks.—It is easily apparent that the differences in the three forms of the genus *Pauxi* now known are found mainly in the casque, which varies from the cylindrical, somewhat tapering form seen in the two known specimens of *P. unicornis* to the considerably swollen, figlike shape of typical *pauxi*, with *gilliardi* coming between (Figs. 1 and 2). The feathers of the center of the crown, nape, and hind neck in *unicornis* are stiffer and are glossy, instead of soft and velvety, but tendency toward this condition is found also in *pauxi* and *gilliardi*.

Comparative measurements (in mm.) of the casque in all available material follow, those registered for *gilliardi* including the nine heads from Indian necklaces in the Phelps collection:

	11 *pauxi*	13 *gilliardi*	2 *unicornis*
Culmen, from base of casque	32–39	29–36	32–35
Greatest width of casque	28–40	19–27	20
Greatest depth of casque	30.5–38	21–27.1	23
Greatest circumference of casque	93–117	63–85	66–75

The three races will stand therefore as follows:

PAUXI PAUXI PAUXI (Linnaeus)

Mountain forests of northwestern Venezuela from near Caracas, through the Cumbre de Valencia to the Mérida region.

PAUXI PAUXI GILLIARDI Phelps and Wetmore

Forests of the Sierra de Perijá from the western slope in Colombia east of Fonseca, Magdalena, and the Montes de Oca, Guajira, Colombia, around to the headwaters of the Río Negro above Machiques in Venezuela, probably extending much farther south.

PAUXI PAUXI UNICORNIS Bond and de Schauensee

Known from two specimens from near Palmar, Yungas de Cochabamba, Bolivia.

The form of the casque varies somewhat with age. Carriker secured a young female of *gilliardi* at Monte Elias, Magdalena, Colombia, on August 11, 1941, that apparently is not quite half grown. It already has the plumage of the adult, except that a few bright brown feathers of the young plumage are still found in the crown, some of the wing coverts and back feathers are tipped, or occasionally mottled lightly with bright brown and buff, the secondaries and tertials are mottled somewhat with bright brown and the feathers of the sides, lower breast, and legs are tipped with whitish to buffy brown. The casque in this bird is merely a rounded knob above the base of the culmen, rising about 7 mm from a base that is approximately 15 mm long and 8 mm wide. Gilliard's notes describe an immature *pauxi* in the American Museum of Natural History (no. 471586) with the casque about two-thirds developed which has the greatest circumference about 80 mm. One or two of the heads of *gilliardi* in the Phelps collection may be younger than the others as indicated by the smaller casque. The most southern race, *unicornis*, has the casque more uniformly cylindrical throughout. The two northern forms are marked by a posterior swelling that reaches its maximum development in typical *pauxi*.

Linnaeus[4] based the description of his *Crax pauxi* on the accounts of Aldrovandus, Willughby, Hernandez, Edwards, Brisson, and other early authors, and from these sources indicated that the bird came from "Mexico." The occurrence of the species has been in much confusion with various erroneous localities included. From present knowledge it appears probable that the few examples seen by the early writers came from Venezuela, since that is the section of the known range ordinarily accessible to the

[4] Systema naturae, ed. 12, 1: 270. 1766.

early travelers. We, therefore, designate the type locality as near Caracas, Venezuela, since in early days forests suitable for *Pauxi* were found near the city.

As regards the altitudinal distribution of these birds it is erroneous to limit them to the Tropical Zone. Two specimens of *Pauxi* in the Phelps collection were obtained in the Cumbre de Valencia, Carabobo at 1,440 meters (4,725 feet), and at Cubiro, Lara, at 1,900 meters (about 6,200 feet). These are in the lower edge of the Subtropical Zone.

We have pleasure in naming the new form for E. Thomas Gilliard, in recognition of his work on the material on which it is based.

Specimens examined.—Pauxi p. pauxi. Venezuela: (American Museum of Natural History) 3 ♂, 7 sex ?, Montañas del Capás, Mérida region (Briceño); 1 ♂, Limones, Río Limones, Mérida region; 1 sex?, zoo specimen; 1 sex?, "northwest Venezuela" (mounted). (Academy of Natural Sciences of Philadelphia) 3 sex?, zoo specimens; 1 sex?, "northern South America." (Phelps collection, Caracas) 1 ♂, Cumbre de Valencia, Carabobo, at 1,440 meters; 1 ♀, Cubiro, Lara, 1,900 meters.

Pauxi p. gilliardi. Colombia: (U. S. National Museum) 1 ♂, El Bosque, 1,800 feet elevation, in the Sierra Negra, near Carriapia, Guajira; 1 ♂ (type) Tierra Nueva, 1,200–1,500 feet in the Sierra Negra, Magdalena; 2 ♀ adult, 1 ♀ juvenile, Monte Elias, 4,500 feet in the Sierra Negra, Magdalena. Venezuela: (Phelps Collection, Caracas) 9 heads, sex?, on the Río Negro above Machiques, in the Sierra de Perijá, Zulia.

Pauxi p. unicornis. Bolivia (Academy of Natural Sciences of Philadelphia) 1 ♂ (type), 1 ♀, hills above Bolívar, 2,500 feet elevation near Palmar, Yungas de Cochabamba.

MAMMALOGY.—*The systematic status of certain pocket gophers, with special reference to* Thomomys monticola.[1]

E. A. GOLDMAN, Fish and Wildlife Service.

In various papers published during recent years the writer has made efforts to bring together in specific or near-specific groups many of the names proposed for pocket gophers during a pioneer period when systematic relationships were very imperfectly known. Our knowledge of these relationships is still far from complete, but, especially in view of the extraordinary number of names involved, some semblance of systematic order is imperative. In dealing with the names the term "group" may conveniently be used rather loosely to designate either an aggregation of subspecies or an assemblage of closely allied species.

In "Remarks on Pocket Gophers, with Special Reference to *Thomomys talpoides*" (Journ. Mamm. 20: 233. May 14, 1939), I traced the local range of the *Thomomys talpoides* series south in western Washington to the Columbia River. The apparent replacement of populations of the *talpoides* type by the *Thomomys monticola* series in the Pacific coast region south of the Columbia River was also noted, but the subspecies were not formally segregated, and such confused combinations as *Thomomys douglasii oregonus* Merriam have remained in current literature. At the suggestion of Gerrit S. Miller, Jr. certain names are here revised in order to make them available for inclusion in a new list of North American mammals being prepared by him.

[1] Received March 11, 1943.

LIST OF SUBSPECIES OF THOMOMYS MONTICOLA, WITH TYPE LOCALITIES

Thomomys monticola monticola Allen: Mount Tallac, Eldorado County, Calif.

SYNONYMS.—*Thomomys monticola pinetorum* Merriam: Sisson, west base of Mount Shasta, Siskiyou County, Calif.; *Thomomys monticola premaxillaris* Grinnell: 2 miles south of South Yolla Bolly Mountain (7,500 feet), Tehama County, Calif.

Thomomys monticola oregonus Merriam: Ely, near Oregon City, Willamette Valley, Clackamas County, Ore.

Thomomys monticola hesperus Merriam: Tillamook, Tillamook County, Ore.

Thomomys monticola niger Merriam: Seaton, near mouth of Umpqua River, Douglas County, Ore.

Thomomys monticola mazama Merriam: Anna

Creek, near Crater Lake, Klamath County, Ore.

Thomomys monticola helleri Elliot: Gold Beach, mouth of Rogue River, Curry County, Ore.

SUBSPECIES OF THE *THOMOMYS UMBRINUS* GROUP NOT PREVIOUSLY RECOGNIZED AS SUCH

Thomomys umbrinus quercinus Burt and Campbell: Peña Blanca Spring, altitude 4,500 feet, near Mexican boundary, north of Monument 128, Pajarito Mountains, Santa Cruz County, Ariz.

Thomomys umbrinus proximus Burt and Campbell: Old Parker Ranch (Pickett's Ranch on U. S. Geological Survey topographic map, Patagonia Quadrangle, edition of August 1905), altitude 4,800 feet, west slope of Santa Rita Mountains, Pima County, Ariz.

SUBSPECIES OF *THOMOMYS BOTTAE* HITHERTO TREATED AS DISTINCT SPECIES

Thomomys bottae magdalenae Nelson and Goldman: Magdalena Island, Lower California, Mexico.

Thomomys bottae martirensis Allen: San Pedro Martir Mountains (8,200 feet), Lower California, Mexico.

Additional specimens of *Thomomys bottae collinus* Goldman, from Fly Park (9,000 feet), Chiricahua Mountains, Ariz., indicate that the characters ascribed to *Thomomys umbrinus chiricahuae* Nelson and Goldman, from Pinery Canyon (7,500 feet), Chiricahua Mountains, Ariz., are within the range of individual variation in that subspecies. The name *Thomomys umbrinus chiricahuae* should, therefore, be placed in the synonymy of *Thomomys bottae collinus*.

ICHTHYOLOGY.—*The osteology and relationships of the bathypelagic fishes of the genus* Bathylagus *Günther with notes on the systematic position of* Leuroglossus stilbius *Gilbert and* Therobromus callorhinus *Lucas.*[1] WILBERT MCLEOD CHAPMAN, California Academy of Sciences. (Communicated by LEONARD P. SCHULTZ.)

This report describes the bony structures and the gross visceral anatomy of the genus *Bathylagus*, discusses its relationships, and defines the family Bathylagidae. A brief account is given of the anatomy of *Leuroglossus stilbius*, and reasons why it should be placed in the Bathylagidae rather than the Argentinidae are listed. *Therobromus callorhinus*, known only from bones found in the stomachs of the fur seals of the North Pacific, is identified as a species of *Bathylagus*.

The genus *Bathylagus* comprises at present 16 species of fishes, 8 of which have been described in the past 12 years. Representatives occur on both sides of the North and South Atlantic Oceans, in the Antarctic, off the west coast of North America from southern Mexico to the Bering Sea, and in the Okhotsk Sea. They typically inhabit deeper water layers outside the continental shelf (Norman, 1930; Parr, 1931 and 1937; Beebe, 1933; Chapman, 1939 and 1940), although *B. argyrogaster* has been taken toward the surface layers (Norman, 1930).

Bathylagus was originally placed by Günther (1878) in the Salmonidae. Regan (1909 and 1914) considered it to be a member of the Argentinidae, and Norman (1930), Parr (1931), Beebe (1933), and others have followed him. Jordan and Evermann (1896) placed it in the Microstomidae, as did Barnard (1925) and others. In recent years it has been placed both in the Argentinidae and Microstomidae by the compilers of the Pisces section of the Zoological Record. Gill (1884), with his usual keen insight, erected for the genus the family Bathylagidae by name only, but Goode and Bean (1895) gave a diagnosis of the family. Gill's classification has been followed by Jordan (1923), Jordan, Evermann, and Clark (1930), Fowler (1936) Parr (1937), and most recently by Berg (1940).

This study is based upon dissections of *Bathylagus pacificus* Gilbert taken by the International Fisheries Commission in the Gulf of Alaska and off the coast of British

[1] Received February 11, 1943.

Columbia. The illustrations are based on an adult female, with well-developed eggs, taken off the west coast of the Queen Charlotte Islands, IFC station 321c (Thompson and Van Cleve, 1936). Diagnoses have been made on specimens of *B. alascanus* Chapman and *Leuroglossus stilbius* Gilbert. Unless otherwise mentioned, references to the anatomy of *Argentina*, *Microstoma*, and *Macropinna* are based upon dissections by the writer.

It is a pleasure to acknowledge the kindness of H. A. Dunlop, director of investigations, International Fisheries Commission, in allowing me to work on their specimens of *Bathylagus* and *Macropinna;* Dr. George S. Myers, Stanford University, in providing me with a specimen of *Leuroglossus;* and Dr. Leonard P. Schultz, curator of fishes, U. S. National Museum, for the loan of specimens of *Argentina* and *Microstoma*.

ANTORBITAL PORTION OF CRANIUM

Ethmoid cartilage (Figs. 1–3) restricted in extent by size of ethmoid and prefrontal ossifications; extending anteriorly as broad, flat plate between dorsal and ventral ethmoid bones; thickest between prefrontals where it rises to frontals and shows between them; pierced on inner edge of prefrontals by foramina of olfactory nerves; extending unbroken under frontals to sphenotics, thus separating orbitosphenoid and alisphenoids from frontals; ventral surface flat, with palatine synchondrized along entire edge anterior to prefrontals as in *Macropinna* (Chapman, 1942b); running posteriorly for short distance along parasphenoid.

Mesethmoid (Figs. 1, 3) consisting of a nearly circular, flat plate, which forms greater part of rostral plate, and a strong buttress, which rises from dorsal surface of this plate to meet frontals.

Ventral ethmoid (Fig. 2) a thin circular plate like mesethmoid above it; shallowly concave on ventral side; perhaps homologous with similar bone in certain osmerids (Chapman, 1941b).

Frontals (Figs. 1–3) everywhere separate, with cartilage exposed between them posteriorly, anteriorly, and between orbits; lying over only a portion of edges of sphenotics and supraoccipital posteriorly; sloping evenly and gently downward from supraoccipital to mesethmoid. Each bone bearing on its lateral edge a high and prominent trough in which frontal extension of lateral line system lies and to which broad, thin supraocular and postfrontal of circumorbital series are attached membranously; these structures probably special ossifications of sensory system, but indistinguishably fuse with frontals; higher anteriorly than width of frontals between them and responsible for concavity of interocular region; formed from extremely thin bone and quite separate from broad supraorbitals.

Prefrontals (Figs. 1–3) thin, broad ossifications of nearly circular shape in lateral ethmoid cartilage, with very thin lateral edges.

Parasphenoid (Figs. 2, 3) long, slender, and straight, extending from ventral ethmoid to basioccipital; concave on ventral surface under ethmoid, with broad posterior shaft of vomer lying in cavity; heaviest and widest where it reaches prootics; posterior extension of bone thin and lying flatly in shallow concavity of basiooccipital. No true myodome. Parasphenoid flatly attached to prootics and heavy cartilage between those bones so ocular muscles attach in shallow concavity formed by short wings of parasphenoid and bulky ventral edges of prootics.

Vomer (Figs. 1–3) heavy and large, projecting anteriorly beyond ethmoid structures; on anterior edge bearing 30 to 32 conical teeth, which are set in sockets in bone, project slightly anteriorly as well as ventrally, and form entire dentition of upper jaw; a notch in bone at lateral corner of dentigerous area into which anterior end of palatine fits; long, broad, median shaft projects back in concavity of ventral ethmoid to end on parasphenoid.

POSTORBITAL PORTION OF CRANIUM

Cartilage of postorbital portion of cranium everywhere restricted in extent (Figs. 1–3); reduced to narrow bands, which disappear between supraoccipital and epiotics; expanded between supraoccipital and sphenotics, but these areas covered by parietals; somewhat expanded between epiotics and exoccipitals; greatest expansion between basioccipital and prootics, but considerable part of this covered by parasphenoid; sockets of hyomandibula lines with cartilage.

Dorsal surface of postorbital portion of

cranium with no prominent ridges or depressions, sloping gently and evenly from parietals to posterior edge of pterotics without definite temporal fossae, and sloping between conical tips of epiotics and supraoccipital down to foramen magnum.

Supraoccipital (Figs. 1, 2) broad and shield-shaped, forming prominent portion of dorsal surface of cranium; anterolateral edges of bones covered by parietals; lateral portion of anterior edge covered by frontals, but median portion exposed; bluntly pointed posterior end sloping downward, but broadly separated from foramen magnum by epiotics and exoccipitals; short, sharp vane of bone projecting from midline, on which originate two thin but tough muscles, which extend back between myomeres and along distal ends of interneurals to origin of dorsal fin.

Thin, scalelike parietals (Figs. 1, 3) widely separated by supraoccipital, partially covering sphenotics and supraoccipital and completely covering cartilage between those bones.

Epiotics (Figs. 1, 3) prominent, conical bones meeting broadly behind supraoccipitals, receiving ligament from dorsal fork of posttemporal on blunt tip of bone, and each with deep concavity on posterior surface.

Sphenotics (Figs. 1–3) prominent bones with considerable dorsal, lateral, and anterior surface. Socket of hyomandibular resting not so much on sphenotic as upon cartilage between that bone and prootic.

Pterotics (Figs. 1–3) with socket of hyomandibular angling across entire ventral surface of each bone. From dorsal surface a long, bulky column of cartilage, which joins ventral and dorsal surfaces internally, can be seen.

Alisphenoids (Figs. 2, 3) large bones providing anterolateral protection for brain; separated from prootics, sphenotics, and orbitosphenoid by slender bands of cartilage, and everywhere separate ventrally.

Orbitosphenoids (Figs. 2, 3) meeting mesially but not completely fused; from ventral edge a very thin strand of ossification extends into interorbital membrane; olfactory nerves emerging between bones anteriorly.

Ventral side of cranium marked by triangular expansion of basioccipital and prootics, in which the large otoliths lie. Otolith capsules not projecting ventrally as much as in *Macropinna* or the osmerids.

Prootics (Figs. 2, 3) largest bones of ventral surface of cranium, marked by otolith expansions and by small posterior foramen of trigeminofacial complex; these two foramina separated by thin, strongly ossified bridge, which forms sharp ridge setting off anterior from ventral surface of bone; bones separated ventrally by broad, thick band of cartilage; anterior end of this cartilage much thickened and slightly concave, with shallow concavity between it and parasphenoid. Posterior eye muscles inserted in this area.

Each exoccipital (Figs. 1–3) strongly concave on ventral side with two foramina in posterior part of concavity, the posterior of which is much the larger; posterior projection of bone lying along condyle of basioccipital, sending process dorsally, separated from similar process of other exoccipital by narrow band of cartilage; these two processes form sides and roof of foramen magnum but do not form part of condyle and do not articulate with any process of first vertebra; concavity of posterior surface of epiotic continued on posterior surface of exoccipital.

Constricted posterior end of basioccipital (Figs. 1–3), which forms occipital condyle, heavily ossified and bearing ridges of denser ossification ventrally and laterally; ventral surface of bone shallowly concave anteriorly.

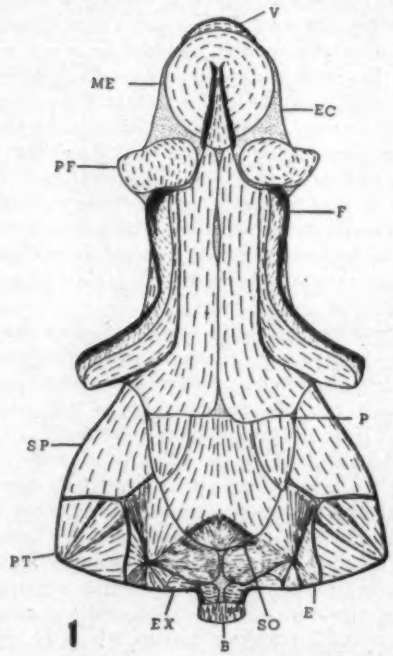
Opisthotic (not shown in Fig. 3) tiny and oblong; in some specimens lying entirely on exoccipital midway between foramen of vagus nerve and lateral edge of bone, and in others lying more laterally and partially resting on cartilage between exoccipital and pterotic; curving around posterior edge of exoccipital and thus with a small posterior surface which is not visible dorsally; receiving ligament from ventral fork of posttemporal.

SPECIAL OSSIFICATIONS OF SENSORY SYSTEM

All bones associated with extension of lateral line system over head thin and weak, most with no tubes developed for protection of nerves, but acting merely as supports. Nasal thin, slender, semitubular, and almost flattened; lying directly over nasal capsule; by no means so big or broad in my specimens as in Beebe's (1933, fig. 37). Six bones of circumorbital series as shown by Beebe, except that in my specimens postorbital considerably larger than supraorbital. It is interesting to note the turn evolu-

tion has taken in the big-eyed *Bathylagus*, whose eyes are placed laterally and strongly protected dorsally by the expanded supraorbital and postorbital; whereas in the big-eyed *Opisthoproctus* (Trewevas, 1933) and *Macropinna* (Chapman, 1942b), which have the eyes dorsally directed, these bones are absent and the eyes are protected by enormously expanded suborbitals, bones that are weakly developed in *Bathylagus*.

A semitubular bone, attached to sphenotic directly behind eye, bridging gap for nerve between sphenotic and preopercle. Nerve encased in tube on dorsal arm of preopercle, but on ventral arm this tube opens ventrally to become trough. A short tube protects nerve on lateral face of opercle, projecting downward from condyle. Protection for nerve over sphenotic and pterotic irregular, not tubular and exceedingly flimsy. Lightly ossified tissue lending some support to nerve between cranium and supracleithrum. Nerve running ventrally on supracleithrum in trough of thin bone securely ankylosed to that bone. Ossified tube for nerve present on mandible, securely ankylosed to both dentary and angular.



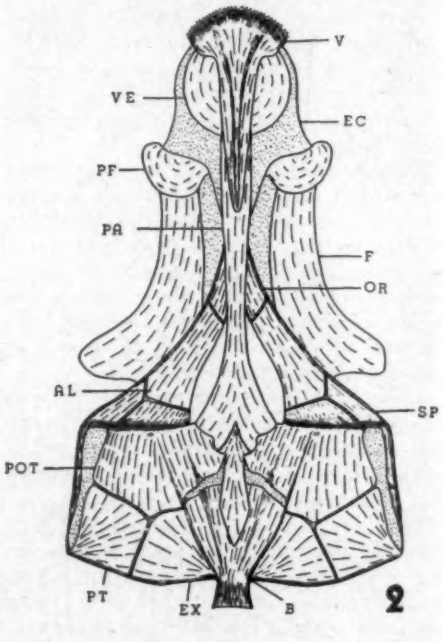


Fig. 1.—Dorsal view of the cranium of *Bathylagus pacificus*. Fig. 2.—ventral view of the cranium of the same. ×3.2.

UPPER JAW

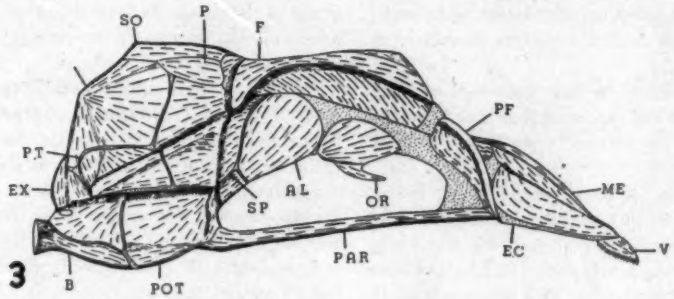
Premaxillary and maxillary thin and delicate, neither bearing teeth nor having gape edge thickened for that purpose (Fig. 4); upper jaw loosely bound to cranium by delicate membranes only, neither bone equipped with anterior condyle for attachment to cranium; anterior end of premaxillary lying in groove between anterior end of mesethmoid and vomer, not meeting premaxillary of other side; bound rather loosely to premaxillary but not to palatine. No supramaxillary found in any specimen (such a bone is shown by Beebe, 1933, in fig. 36, but not in fig. 39, and is not mentioned by him in the text).

MANDIBLE

Mandible (Fig. 4) consisting of dentary, articular, angular, sesamoid articular, Meckel's

cartilage, and a superficial ossified tube for mandibular branch of lateral line system. Dentary forming greater part of mandible, so thin that sesamoid articular can be seen through it in stained specimens; overlying considerable portion of articular; bearing 82 teeth in specimen drawn, which are conical, small, and closely pressed together in a single series. Angular small but heavily ossified, receiving broad ligament from interopercle. Articular triangular with heavily ossified socket of articulation at apex, with strong, thick shaft of bone extending forward from socket on mesial side, presumably ossification of posterior third of Meckel's cartilage.

Meckel's cartilage about one-third length of mandible, extending from above-mentioned interior shaft of articular to a similar but slenderer shaft on inner side of dentary; not thick, but broad posteriorly. Sesamoid articular thin and of irregular shape, with longest axis anterior-posterior, and area about one-third that shown for articular (Fig. 4); lying principally on dorsal edge of Meckel's cartilage, but extending also onto articular and dentary. Thin ossified tube for mandibular branch of lateral line system on external side of dentary and articular, obviously a special ossification of sensory system but indistinguishably fused to the mandibular bones. Sensory canal communicates with exterior by means of four pores in the bone.



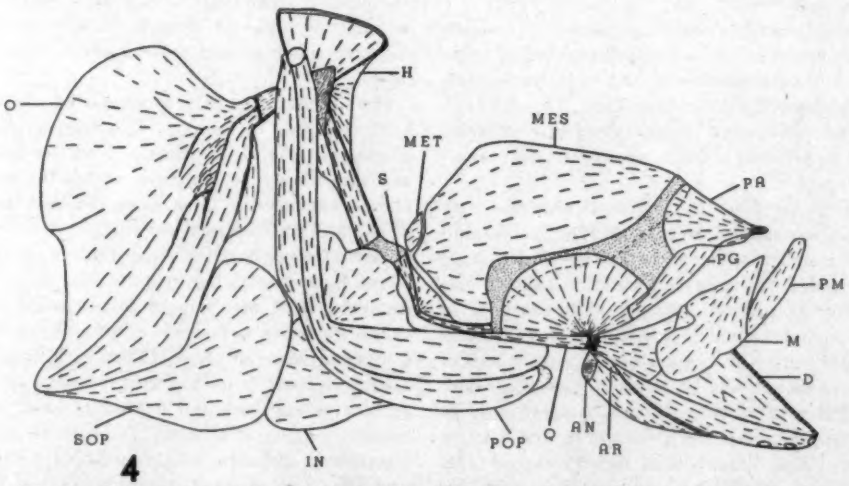


Fig. 3.—Lateral view of the cranium of the *Bathylagus pacificus*. Fig. 4.—Lateral view of the suspensorium of the same. ×3.2.

PALATINE ARCH

Palatine (Fig. 4) securely joined along entire

dorsal edge to ethmoid cartilage as in *Macropinna*, thus forming firm support between bones of oral cavity and cranium; band of cartilage behind palatine also participating in this junction. Anterior end of palatine more heavily ossified than rest of bone and inserted in cavity between vomer and ethmoid cartilage; no teeth on palatine of specimens examined, but since vomerine dentition extends posteriorly under anterior tip of palatine, the latter appears to bear a few teeth until a complete dissection is made.

Pterygoid (Fig. 4) simple, well-ossified bone joining palatine and quadrate together strongly, overlapping both bones laterally as well as mesially.

Quadrate (Fig. 4) has form of nearly half a circle, with small but heavily ossified condyle; slender process projecting posteriorly along preopercle and symplectic, thus binding palatine and hyoid arches together and binding both to preopercle.

Broad band of cartilage around quadrate forms broad patch between quadrate and palatine and extends around end of latter to synchondrize with ethmoid cartilage. This does not extend posteriorly along symplectic. Simple, thin membrane between symplectic and mesopterygoid.

Mesopterygoid (Fig. 4) broad, thin and very similar to same structure in *Macropinna* and *Opisthoproctus* (Trewevas, 1933); ventral edge lies under quadrate and palatine (dotted line in Fig. 4), and entirely mesial to cartilage of this region, to which it is tightly bound. Bone appears to be an ossification of membranes of roof of mouth and therefore not properly considered with cartilage bones of palatine arch. Metapterygoid either absent or represented by small bit of bone behind mesopterygoid (Fig. 4). Of same structure as mesopterygoid and separated from that bone by thin membrane only; doubtfully homologous with metapterygoid of other isospondylous fishes.

HYOID ARCH

Hyomandibular (Fig. 4) articulating along full lateral surface of pterotic and sphenotic as in *Macropinna* and *Opisthoproctus* (Trewevas, 1933). Articulation anteriorly on cartilage between sphenotic and prootic. Opercular condyle nearly as long as articular head although much slenderer, leaving considerable open space between opercle and preopercle. High, thin wing of bone extending from lateral side of hyomandibular at level of opercular condyle attached by membranes to preopercle and adjacent bone of circumorbital series. Truncus hyoido-mandibularis facialis nerve pierces bone in large foramen which extends nearly straight ventrally from inner to outer side of bone to emerge on thin wing of bone on posterior side of shaft of hyomandibular. Wing of thin bone present in anterior angle between articular head and ventral shank of the bone.

Column of cartilage between hyomandibular and symplectic (Fig. 4) with characteristic anterior twist so that symplectic does not continue in direct line with ventral shaft of hyomandibular. A similar condition is found in *Opisthoproctus* (Trewevas, 1933). Interhyal articulates with mesial side of this cartilage.

Symplectic (Fig. 4) a semicylindrical shaft bent forward near its middle to form an approximately right angle with wing of thin bone in angle. Symplectic extends to, but not beyond, cartilage around posterior edge of quadrate.

Hyoid apparatus (Fig. 5) consisting of interhyal, epihyal, ceratohyal, two hypohyals, a glossohyal (Fig. 6, not Fig. 5), and two broad and thin branchiostegal rays, except for latter all bones sturdy and thick, being heaviest bones of skull. Branchiostegal rays inserted entirely on cartilage surrounding ventral side of epihyal. Ceratohyal constricted in its middle and with numerous irregular ridges of denser ossification there. Posterior two-thirds of glossohyal (Fig. 6) ossified; anterior broader third cartilaginous. Dental cement bone covering most of dorsal surface of cartilage and extending back onto ossified portion of element. It bears no teeth, but since it presents a hardened, fairly sharp, and slightly upturned anterior edge, it conceivably may be of considerable aid in handling live food.

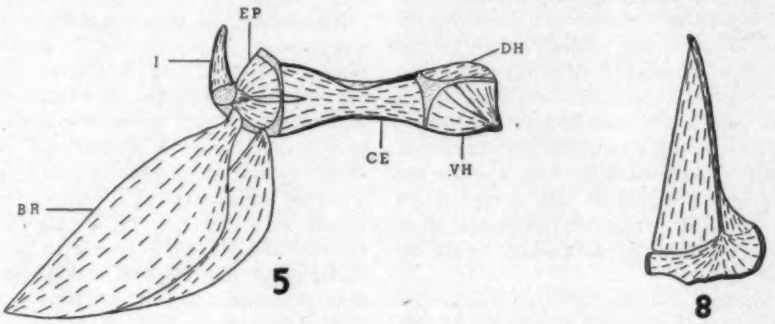
OPERCULAR APPARATUS

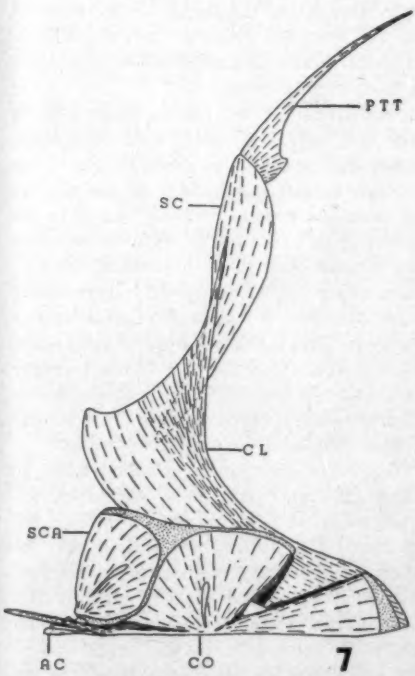
All four opercular elements present (Fig. 4); all thin, flexible bones. A few rays of denser ossification radiate outward from socket of articulation of opercle. Short tube protecting portion of lateral line system running downward from articulation along exterior face of that bone. Subopercle extends into space between opercle and preopercle but does not fill it. Por-

tion of posterior edge of bone covered by opercle. Long, slender interopercle nearly covered by horizontal arm of preopercle; its anterior end attached by a broad ligament to angular and posterior end securely attached by membranes to subopercle. Broad wing of thin bone present in angle of preopercle. Sensory canal tubular on vertical arm of preopercle and with numerous small openings to surface dorsally, but ventral edge of canal separated from main bone on horizontal arm and tube becomes a trough. An interspace present between vertical arm and lower end of hyomandibular, and between horizontal arm and symplectic, both closed only by thin membranes.

GILL ARCHES

First three basibranchials (Fig. 6) ossified but cartilaginous on both ends; ossified portions of all three round in cross section. Last





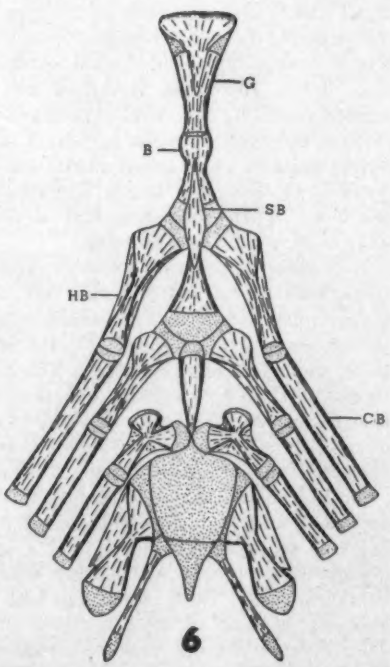


Fig. 5.—Lateral view of the hyoid apparatus of the *Bathylagus pacificus*. Fig. 6.—Dorsal view of the ventral half of the gill arches of the same. Fig. 7.—Mesial view of the shoulder girdle of the same. Fig. 8.—Dorsal view of the right pelvic bone of the same. All figures are ×3.2.

two basibranchials entirely cartilaginous, presenting a flat dorsal surface but with a constriction marking off two on ventral surface. Dental cement bone joining dorsal surfaces of first and second basibranchials and covering a portion of cartilage between them, probably homologous with larger element in same position in osmerid fishes and *Plecoglossus* (Chapman, 1941a). It bears no teeth.

Hypobranchials (Fig. 6) present on first three arches. Those of third arch with anterior process, which projects ventrally to a slight degree. One can visualize the possible origin of the peculiar third hypobranchial of the Osmeridae and Plecoglossidae from this structure. If the posterior process (the main portion of the bone) diminished to nothing, until the ceratobranchial touched the fourth basibranchial, and the anterior process elongated and turned more ventrally until it surrounded the ventral aorta the osmerid third hypobranchial would be achieved.

Ceratobranchials (Fig. 6) on all five arches. First three bent dorsally a little at middle. Small muscle that originates on the hypobranchial inserted on slight projection from ventral side of bone at this bend. Fourth ceratobranchial broad, somewhat thickened and constricted anteriorly to an hour-glass shape. Wide shelf of thin bone present in lateral (or anterior) angle on which broad muscle extending dorsally to expanded fourth suprabranchial originates. Fifth ceratobranchial a slender, weak bone, which bears no teeth.

First three epibranchials ossified, and each bears, near mesial end of dorsal side, a cartilage-capped process that articulates with similar processes from, respectively, the second, third, and fourth suprabranchials. This process largest on third epibranchial. Fourth epibranchial entirely cartilaginous and reduced to band of cartilage attached firmly to ventral edge of expanded fourth suprabranchial.

No suprabranchial found on first arch. Second small and flat with dorsoanterior process reaching to first epibranchial and a smaller dorsoposterior process articulating with third suprabranchial. Third suprabranchial more elongate because of long anterior process. Fourth suprabranchial broadly expanded and little resembling others; turned nearly at right angles to plane of other suprabranchials and extending dorsally until band of cartilage around its dorsal end articulates with cranium. Broad muscle inserted over entire posterior surface of bone extending directly ventrally to fourth ceratobranchial. This muscle must be of considerable importance in the movements of the gill arches. An identical apparatus is found in *Microstoma* and *Macropinna* and probably *Opisthoproctus* (Trewevas, 1933).

SHOULDER GIRDLE

All elements of shoulder girdle weak, thin, and more or less pliable (Fig. 7). Posttemporal consists mostly of long, thin dorsal fork, curving backward somewhat, in manner not possible to show in Fig. 7, to resemble a sickle, lying over dorsal corner of epiotic and separated from posttemporal of opposite side only by tendon from supraoccipital. Strongly attached to epiotic by a ligament, which extends forward from its attachment to epiotic to lie flatly on under side of posttemporal so that latter can be drawn backward some little bit but can not be pushed forward at all. It would thus aid somewhat in dissipating the thrust of the pectoral fin to the cranium. Ventral fork of posttemporal short, blunt, and attached to opisthotic by a fairly strong ligament.

Supracleithrum thin, pliable bone bearing lateral line nerve on outer side in trough. Whether this trough is an integral part of the bone or a special ossification of the sensory canal that has become securely fused to the supracleithrum could not be determined. Cleithrum largest bone of girdle, ending dorsally in long, sharp spike. Completely ligamentous first rib attached to this and supracleithrum, not only to bind girdle securely to axial skeleton but also to bind the two bones together. Lateral-anterior face of bone broadened for insertion of sternohyoideus muscle on outer surface, and muscles of fin on inner surface.

Primary shoulder girdle attached flatly by cartilage to inner surface of cleithrum and curving away at angle of not more than 45°. Both scapula and coracoid fairly large, but neither very strongly ossified. Scapular foramen a mere elongated slit and entirely contained within bone. Coracoid with similar foramen of about same size and shape and another, much smaller, opening near ventral end of that. Anterior process of coracoid strong and

broad with V-shaped interosseus space between it and main part of bone. Posterior process elongate and slender, projecting posteriorly well beyond actinosts. Posterior two-thirds of this spike cartilaginous and pliable. In one specimen this elongate projection was either absent or unwittingly lost in dissection. Four actinosts tiny, placed closely together and all based on cartilage between scapula and coracoid. No mesocoracoid or postcleithra.

PELVIC GIRDLE

Support of small pelvic fins slight and weak (Fig. 8); consisting of a single, elongate triangular bone on either side which tapers to a point anteriorly. Except for posterior side of triangle bone thin and pliable in spite of border of heavier ossification along outer side. Posterior edge thickened and cartilaginous for support of fin rays. Mesially two prongs, ventral and dorsal, project from thickened posterior end to meet similar prongs of opposite pelvic bone. Dorsal prong broad, completely ossified, except for thin band of cartilage around its edge of junction, and arching dorsomesially. Two ventral prongs, slenderer and bluntly pointed, meet mesially just under skin. For mesial third of their length both are entirely cartilaginous. Two pelvic bones rather weakly joined together.

AXIAL SKELETON

Forty-two complete vertebrae plus single upturned terminal centrum present. First semblance of haemal spine, a short, sharp stub to which rib of each side attaches, occurs on sixteenth vertebra. Spine of seventeenth vertebra slender and about one-half as long as longest haemal spine. That of eighteenth vertebra longer yet and that of nineteenth of full length. Sixteenth vertebra thus first caudal vertebra, but anus placed back much farther, under twenty-sixth vertebra. Rib of sixteenth vertebra of full length. Ribs also on seventeenth, eighteenth, and nineteenth vertebrae. Each somewhat shorter than one preceding until that of nineteenth only about half length of that of sixteenth vertebra. These last three ribs very loosely attached by membranes to their respective haemal spines. All ribs are exceedingly slender and pliable and seem to give slight protection to abdominal cavity.

Both epineurals and epipleurals present; all scarcely thicker than muscle fibers. Last epipleural noted posteriorly was on rib of sixteenth vertebra and last epineural posteriorly was on twentieth neural spine, but because of their delicacy it cannot be securely stated that they do not occur farther back on the caudal vertebrae.

Centra all completely ossified, elongate, slender, hour-glass shape. Parapophyses of precaudal vertebrae, while broad, quite thin. Two of each centrum not joined ventrally. A considerable interspace between those of succeeding centra. Ribs flattened and slightly broadened on proximal ends and lying flat on external side of parapophyses.

Neural spines, especially of first 13 vertebrae, exceedingly slender and thin except for their broadened proximal ends where they attach to centra. Those of each side of a single centrum do not touch, even at their filamentous distal ends, on first 13 vertebrae. Those of fourteenth and all succeeding vertebrae join and become firmly ankylosed directly above spinal cord and thus form a single spine. These spines considerably heavier and stronger than those on anterior vertebrae. About eight to ten times as much of spinal cord exposed between succeeding neural spines as covered by bases of slender spines.

Nine interneurals between cranium and first baseost of dorsal fin. Each of these except ninth inserted between distal tips of succeeding neural spines. Ninth lies in same interspace as eighth, although with normal spacing between them. It appears to have been crowded out of its normal place by the enlarged, bifid, first baseost of the dorsal fin. Each interneural capped on either end with cartilage, heavier than neural spine, well ossified, and approximately round in cross section. Between all interneurals is developed an apparatus that the writer has not seen so well developed in dissection of any other fish. This consists of a rather strong ligament running from the distal end of each interneural nearly ventrally to a little below the middle of the next interneural posteriorly. This is not a single ligament but is made up of several fibers, some of which are inserted on the cartilage cap, some on the bone proper. This set of ligamentous connections between the interneurals unites them all into a

single apparatus starting with the broad ligament between the supraoccipital and first interneural, and attached lightly to the first baseost of the dorsal fin. It has the effect of dispersing any strain coming to the anterior member (the cranium) throughout the entire apparatus.

No ribs, epineurals, or epipleurals on first vertebra, and no interneural between first neural spine and cranium. In place of a rib a strong ligament of similar diameter as a normal rib strongly attached to shoulder girdle (as noted above). In my specimens ribs of second vertebra fully developed and as large as any others.

Eight baseosts for dorsal fin, each supporting a fin ray. First longest and largest, bifid ventrally but reaching only to, and not straddling, neural spine of tenth vertebra. Eighth very small and consists of little more than distal knob for insertion of fin ray. Other baseosts all similar, differing only in becoming progressively shorter from second to seventh. Each bone ends distally in heavy knob and tapers ventrally to slender proximal end. All latter widely separate. Baseosts several times heavier than corresponding neural spines. Distally each baseost connected with next one posteriorly by small hour-glass-shaped bone. Each of these bones cupped on each end and each cup lined with cartilage. Dorsal line of baseosts thus solid and strong for support of fin, but flexible by reason of 14 small ball and socket joints.

Eighteen baseosts for anal fin presenting flexible, but entire, line distally for support of fin rays by reason of small hour-glass-shaped ossicles between thickened heads of baseosts, as in dorsal fin. Baseosts decrease gradually in length posteriorly until eighteenth is little more than one-third length of first. All slenderer than corresponding supports of dorsal fin. Little if any support gained from slender haemal spines. First baseost bears on its anterior edge, near distal end, a cartilage capped knob to which are attached by tendon two muscles which extend along ventral line of abdomen to shoulder girdle and help to anchor pelvic girdle in place.

Support of caudal fin rather weakly developed. Small dorsal rays of fin extend anteriorly to level of neural spine of thirty-sixth vertebra. Neural spines of last six vertebrae extend to proximal ends of fin rays, very slender, and in no way differentiated for support of rays. Condition essentially the same ventrally except that haemal spine of forty-second vertebra somewhat broadened and thickened distally and covered by cap of cartilage over distal edge of hypural plate to actively support fin. Haemal spine of forty-first and fortieth vertebrae also slightly thickened but lend little support to fin.

None of elements of hypural plate fused together and considerable interosseus spaces left between some. Terminal centrum cone shaped and with pointed end turned upward slightly. Slender, cartilaginous urostyle extends dorsoposteriorly into fin rays as in *Novumbra* (Chapman, 1934) and other fishes. Neural spine of terminal centrum, while thin and weak, widely broadened to fill most of space between last neural spines and urostyle, and covers base of latter. Further dorsally a slender rod of bone lies along upper side of urostyle until latter reaches fin rays. This bone tipped with cartilage distally. Lower side of urostyle sheathed with still another thin bone on which upper three hypurals inserted. Lower four hypurals based on ventral side of terminal centrum. All hypurals capped with cartilage distally and, in addition, with a continuous band of cartilage from urostyle to haemal spine of forty-second vertebra over which proximal ends of fin rays actually ride. Flanges on neural and haemal spines of last several vertebrae shown by Beebe (1933, fig. 41) not present in my specimens.

VISCERA

Stomach J-shaped, large, with very thick walls and covered externally with black pigment. Internally closely packed, deep, thin folds almost fill lumen of stomach so that little space left inside in proportion to size of organ. It is possible, however, that this is capable of considerable expansion, for the stomach of the only specimen cut into was completely empty except for minute flaky particles that could not be identified.

Five pyloric caeca, three moderately good sized, one smaller, and one very short and small. One of larger ones and medium sized one come off ventral side of pyloric region together, former curving upward and posteriorly along left side of pyloric end of stomach, latter curving to right and running anteriorly along py-

loric region. Other three caeca come off right side of pyloric region and lie between it and intestine. Anterior one only a short bud; other two projecting posteriorly, with largest one curving across ventral side of pyloric end of stomach to extend along left side.

Somewhat in advance of pyloric caeca intestine flexes to right and continues straight posteriorly to anus. Anterior two-thirds of intestine rather thin-walled and flabby; lined internally with irregular small folds, which do not project far into lumen and which block off wall into shallow crypts of irregular shape. About two-thirds of remaining third of intestine turgid and nearly cylindrical. It contains a typical spiral valve almost identical in size and shape with that shown by Kendall and Crawford (1922) for *Argentina*. Organ obviously functional and well developed, not vestigial remnant occasionally found in salmon. Spirals made up of spongy, thickened walls with contours as evident in external view as in *Squalus*. Remainder of alimentary tract pigmented, although not so heavily as stomach, and may be termed the rectum, although little different in circumference from spiral valve section.

Specimen examined a female with well-developed eggs. Both ovaries full of eggs and of about same size, with right extending only little more posteriorly than left. Ovaries lay along dorsal side of stomach and nearly enclose intestine clear to rectum. Two sizes of eggs present: larger size about 0.5 millimeter in diameter. Number of large eggs not counted with accuracy but estimated that two ovaries together contained less than 3,000.

Only right lobe of liver present in three specimens examined, but this well developed and covering large part of left surface of stomach. Spherical, translucent gall bladder exactly as found in *Macropinna* (Chapman, 1942b). In one specimen liver notched on ventral edge and gall bladder fitting snugly in this notch over bend of intestine. In another specimen liver covers gall bladder from external view but a bulge in its surface shows presence of bladder in same location.

Kidney similar to that of *Macropinna;* light gray in color and shot through with small black specks. No indication of double structure.

No air bladder (as in *Macropinna*).

SYSTEMATIC POSITION OF LEUROGLOSSUS GILBERT

Dr. George S. Myers has kindly provided me with one of Gilbert's specimens of *Leuroglossus stilbius*. The specimen is small and soft, and the bones are so lightly ossified that they did not take up the stain readily. Therefore it was not possible to give a complete account of its osteology. Definitely there are no mesocoracoids, no postcleithra, and no air bladder. There are only two branchiostegal rays. All osteological characters that can be clearly defined, such as the ethmoid and suspensorium areas (with the mouth parts and vomer), are as in *Bathylagus*. However, the liver is somewhat bilobed; there is a distinct kink in the intestine behind the greater omentum and the intestine is longer than in *Bathylagus;* there are 12 pyloric caeca all in a straight line and the whole of the alimentary tract is enfolded dorsally and ventrally in a double organ which I believe is the greatly enlarged (in proportion to the size of the fish) male sex organs. Because of the above noted characters of the viscera the generic rank should be retained until more complete study indicates otherwise. *Leuroglossus* should be removed from the Argentinidae and placed in the Bathylagidae.

The counts and measurements (in millimeters) of my specimen (*Albatross* station 2904: 1889, southern California) are as follows: anal, 11; dorsal, 10; pectorals, 9; ventrals, 9; caudal, 48. Snout to base of caudal, 48; snout to origin of dorsal, 27½; snout to insertion of ventrals, 29; snout to anal, 38; snout to adipose, 40½; length of head, 17; diameter of eye, 6; depth at pectoral insertion, 8½; length of caudal peduncle, 6; and length of snout, 4¼ mm.

SYSTEMATIC POSITION OF THEROBROMUS LUCAS

Lucas (1899) described the species *Therobromus callorhinus* from bones found abundantly in the stomachs of fur seals in Bering Sea. No intact specimens were available to him, and the species has never been taken alive, nor have specimens been recorded since his original description. He says of it:

"an undescribed isospondylous fish related to the Argentinidae." It has since been referred to the Osmeridae by Jordan, Evermann, and Clark (1930) and Hubbs (1925), but a study of the osteology of the osmerid fishes (Chapman, 1941b) showed that the species was not closely related to those fishes and could not be placed in that family.

Lucas says of the fish: "The species may be diagnosed as follows: Chondrocranium well developed; superior maxillary edentulous; pointed teeth on vomer and anterior portion of palatines; lower jaw very deep; pointed teeth on dentary; articular well developed. Vertebral formula 26 precaudals, 22 caudals, plus 1 hypural; last 4 precaudals with short, wide hypapophyses: other hypapophyses long; neural spines of first 22 vertebrae double, remainder confluent; an epineural present and confluent with basal part of neurapophysis on many of the anterior vertebrae; short transverse processes, directed downward from lower part of anterior vertebrae. Vertebrae simple; anterior but very little shorter than the posterior; centra not sculptured, but bearing many fine longitudinal ridges." The short description was accompanied by a plate of 19 drawings of bones.

The description, except for the number of vertebrae, could have been as correctly drawn from the specimens of *Bathylagus* used as the basis for the present report. The drawings likewise are accurate representations of *Bathylagus*. The chief differences between Lucas's drawings and those in the present report are the result of his specimen being partially digested, and the resemblances are so striking that no detailed description is necessary. The frontals in his specimen, for instance, are gone; part of the opercle is digested away; and part of the hypural plate is gone. The vertebral count given in the description of *Therobromus* by Lucas will aid in identifying his species when specimens of *Bathylagus* from the Bering Sea are available for dissection. Probably his fish was *B. pacificus* or *B. alascanus*.

The discovery that the fur seal feeds extensively on fishes of the genus *Bathylagus* is interesting because this genus in the North Pacific is typically bathypelagic in habitat, indicating that the fur seal feeds at greater depths than is generally recognized. It may be noted that the chief feeding grounds of the fur seal while on the rookeries both on the Pribilof and Komandorskie Islands is outside the 100-fathom contour (Townsend, 1899).

SYSTEMATIC POSITION OF BATHYLAGUS

The affinities of the Bathylagidae are not so close to the salmonoid fishes as is generally supposed. Together with the Argentinidae, Microstomidae, Macropinnidae, Opisthoproctidae, Winteriidae, Xenophthalmichthyidae, and, probably, certain other deep sea fishes, they form a natural group that may be designated as a suborder in the Isospondyli, the Opisthoproctoidei, erected by Berg (1937) for the Opisthoproctidae alone.

Of the fishes with which *Bathylagus* has been associated in the past it resembles *Argentina* least. *Argentina* (Chapman, 1942a) has a well-developed mesocoracoid; a single row of about 30 teeth on the palatine; several heavy recurved teeth on the tongue; small teeth on the fifth ceratobranchial and fourth suprabranchial; the air bladder is large and well developed; there are seven branchiostegal rays; well-developed postcleithra (there are four in my specimen, although Kendall and Crawford (1922) say no "postclavicular" processes are found); the myodome is well developed and opens posteriorly on the basioccipital; the parietals are broadly joined on the midline, nearly occluding the supraoccipital from dorsal view, and form bony bridges across the temporal fossae laterally; and the supraoccipital is broadly separate from the frontals. In view of these differences, and others, *Bathylagus* can not be placed in the Argentinidae.

There are stronger resemblances with *Microstoma*, but that genus has an especially large and prominent air bladder; four branchiostegal rays; well-developed postcleithra; the parietals meet broadly on the midline of the skull; and there are numerous differences in the proportions and arrangements of the bones of the skull, in particular

the special ossifications of the sensory system and the bones of the ethmoid region. For these and other reasons *Bathylagus* can not be considered to be a member of the Microstomidae.

Bathylagus is the representative of a separate family, Bathylagidae (Gill, 1884), to which also belongs *Leuroglossus* (Gilbert, 1890). *Bathymacrops* (Gilchrist, 1922), which Jordan (1923) has placed in the Bathylagidae, should be placed in the Microstomidae as a synonym of *Nansenia*.

SYNOPSIS OF THE FAMILY BATHYLAGIDAE

Opisthoproctoid fishes with adipose fin and enlarged but laterally directed eyes. Supraorbital bones strongly developed and suborbital bones weakly developed. Mouth small. No teeth on tongue, gill arches, premaxillary or maxillary. Teeth on palatine absent or few. Small conical teeth on the vomer and dentary. Mesopterygoid much enlarged but not toothed. Metapterygoid minute, if present. Frontals paired. Both mesethmoid and ventral ethmoid present. Small suprabasal present on basibranchials. Parietals small and widely separated by supraoccipital, which reaches frontals. No definite temporal fossae. No myodome. No mesocoracoid. No postcleithra. Two (as far as known) branchiostegal rays. Gill membranes broadly united. Pectoral and ventral fins small and placed near the ventral outline. Pseudobranchiae well developed. Pyloric caeca few (9 to 12 in *Leuroglossus*, 5 or 6 in *Bathylagus*). Peritoneum and stomach jet black. Air bladder completely absent. Stomach with prominent leaflike projections internally. Intestine short, with well-developed spiral valve.

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ABBREVIATIONS USED ON FIGURES

AC = actinost
AL = alisphenoid
AN = angular
AR = articular
B = basioccipital
BB = basibranchial
BR = branchiostegal ray
CB = ceratobranchial,
CE = ceratohyal
CL = cleithrum
CO = coracoid
D = dentary
DH = dorsal hypohyal
E = epiotic
EC = ethmoid cartilage
EP = epihyal
EX = exoccipital
F = frontal
FM = foramen magnum
G = glossohyal
H = hyomandibular
HB = hypobranchial
I = interhyal
IN = interopercle
M = maxillary
ME = mesethmoid
MES = mesopterygoid
MET = metapterygoid
O = opercle
OR = orbitosphenoid
P = parietal
PA = palatine
PAR = parasphenoid
PF = prefrontal
PG = pterygoid
PM = premaxillary
POP = preopercle
POT = prootic
PT = pterotic
PTT = posttemporal
Q = quadrate
S = symplectic
SB = suprabasal
SC = supracleithrum
SCA = scapula
SO = supraoccipital
SOP = subopercle
SP = sphenotic
V = vomer
VE = ventral ethmoid
VH = ventral hypohyal